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Water Infiltration Control to Achieve Mine Water Pollution Control: The Dents Run Watershed Demonstration Project

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The objective of this study was to demonstrate the effectiveness of surface mined land reclamation measures in establishing surface water infiltration control to prevent or reduce pollution from acid mine drainage. The Dents Run watershed, located in Monongalia County, West Virginia, was the site selected for the study. The project was initiated with a comprehensive field investigation of the watershed to locate and characterize each mine site and underground mine opening. Based on this information and detailed analyses of regional geologic conditions and past mining history, areas of suspected high infiltration were identified. Site specific reclamation plans and specifications were then prepared; these plans were designed primarily to increase surface water runoff and reduce infiltration of surface drainage into underground mine workings through unreclaimed surface mines.

Over 40 hectares (100 acres) of surface mines were reclaimed during this project and nearly 100 percent of the pollutional drainage in the Dents Run watershed was eliminated through the cooperative efforts of government and industry. Virtually all of the mine drainage from the Consolidation Coal Company's active workings was treated to acceptable water quality standards at the Sears and Loar Treatment Plants before discharge. This report defines the project approach, describes each mine site and associated reclamation efforts, outlines monitoring strategies, and analyzes project effectiveness.

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WATER INFILTRATION CONTROL TO ACHIEVE MINE WATER POLLUTION CONTROL

THE DENTS RUN WATERSHED DEMONSTRATION PROJECT

by

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

With the passage of the Surface Mining Control and Reclamation Act of 1977, both federal and state regulatory agencies have become involved in the reclamation of mined lands and the elimination or reduction of mine drainage. This report, which examines the effectiveness of reclamation and treatment techniques to reduce mine drainage from surface and underground coal mines in the Dents Run Watershed near Morgantown, West Virginia, is intended to aid these governmental agencies in the reclamation of mined lands. For further information, contact the Energy Pollution Control Division.

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Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

The objective of this study was to demonstrate the effectiveness of surface mined land reclamation measures in establishing surface water infiltration control to prevent or reduce pollution from acid mine drainage. The Dents Run watershed, located in Monongalia County, West Virginia, was the site selected for the study. This area was replete with unreclaimed surface mines, drift mines, auger mines, refuse dumps, spoil banks, and borehole discharges; all of which were determined to be significant generators of acid mine drainage.

The project was initiated with a comprehensive field investigation of the watershed to locate and characterize each mine site and underground mine opening. Based on this information and detailed analyses of regional geologic conditions and past mining history, areas of suspected high infiltration were identified. Site specific reclamation plans and specifications were then prepared; these plans were designed primarily to increase surface water runoff and reduce infiltration of surface drainage into underground mine workings through unreclaimed surface mines.

Over 40 hectares (100 acres) of surface mines were reclaimed during this project and nearly 100 percent of the pollutional drainage in the Dents Run watershed was eliminated through the cooperative efforts of government and industry. Virtually all of the mine drainage from the Consolidation Coal Company's active workings was treated to acceptable water quality standards at the Sears and Loar Treatment Plants before discharge. This report defines the project approach, describes each mine site and associated reclamation efforts, outlines monitoring strategies, and analyzes project effectiveness.

This report was submitted in fulfillment of Project No. 14010HHG under the sponsorship of the Office of Research and Development, Environmental Protection Agency, and West Virginia Department of Natural Resources by Robins and Associates, Harrisburg, Pennsylvania, and Hittman Associates, Incorporated, Columbia, Maryland. This report covers the period June 1971 to January 1979.

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SECTION 1

INTRODUCTION

Since the inception of coal mining in the United States, West Virginia has been one of the leading coal producing states in the nation. As a result of this extensive mining activity, acid mine drainage has been a significant problem in the northern portion of the state where the interaction of local geologic and hydrologic conditions generally produces severely polluted drainage from both surface and underground mining operations.

The Dents Run Watershed Demonstration Project was designed to address this problem. The project was conducted under the auspices of the Environmental Protection Agency as specified in the provisions of the Water Quality Improvement Act of 1970, PL 91-224. The Act includes a subsection entitled "Area Acid and Other Mine Water Pollution Control Demonstrations." This subsection became Section 14 of the Federal Water Pollution Control Act, as amended. Section 14 provides for the demonstration of techniques for mine drainage pollution control and directs that the Environmental Protection Agency shall require such feasiblity studies as necessary in selecting watersheds for the purpose of demonstration projects. Such feasibility studies are to aid the Environmental Protection Agency in selecting not only the mine drainage pollution control method(s), but also the watershed or drainage area for such application. The Act requires that the Environmental Protection Agency give preference to areas which will have the greatest public value and uses.

In 1971, the Environmental Protection Agency Office of Research and Development awarded a grant for the mine drainage demonstration project described herein. The grant was awarded to the State of West Virginia, Department of Natural Resources. The state, in turn, contracted with the Cyrus Wm. Rice Division of NUS Corporation to conduct the project feasibility study and subsequent reclamation design and monitoring program. As a minimum, reclamation work in the watershed was to be performed in accordance with applicable State and Federal regulations. In addition to this general requirement, however, special or innovative reclamation and abatement techniques were to be employed in areas of suspected high infiltration to reduce drainage into both abandoned and active underground mine workings.

THE PROBLEM

Undoubtedly, one of the most severe mine drainage problems encountered in the Appalachian coal fields is the discharge of highly acidic and iron-bearing drainage from abandoned underground mines. This problem is aggravated by surface water frequently draining into both active and abandoned underground mines through unreclaimed contour surface mines and exposed auger holes. This water then reacts with pyritic material in the roof and floor of underground mines and forms acid mine drainage, a dilute form of sulfuric acid and ferrous sulfate. Since many abandoned underground mines were either developed to the rise or have since intercepted other workings advanced up-dip, the contaminated mine water eventually finds its way to a surface discharge point.

Except in very rare and isolated instances, successfully sealing abandoned underground mine openings to eliminate mine water discharges is not economically feasible and, for all practical purposes, technically impossible using state-of-the art methods. This is due largely to past mining practices where mine openings were often developed from the low side of the coal outcrop and then advanced with the rise of the coal. This mining scheme was employed primarily to facilitate coal haulage. A secondary benefit was also realized because water infiltrating the mine would drain by gravity from the workings, and thus minimize the pumping required to keep active areas dry. In addition to the up-dip mining method, it was also common practice to employ "grass roots" mining. This implies that coal would be mined as close to the outcrop as possible since that was "easy coal" in that haulage costs were minimal. In those times, neither water treatment nor post-mining water quality was a consideration. Consequently, little thought was given to mine sealing. Unfortunately, the combination of weak or fractured barriers and large hydraulic heads, which resulted from these mining practices, have essentially eliminated the possibility of effectively sealing these mines today.

Since mine sealing technology is inadequate for the abatement of acid mine drainage, the only viable alternatives are the perpetual treatment of all contaminated water, or development of at-source controls to eliminate or reduce the volume of water which enters the mine. The prospect of perpetual treatment is not an attractive alternative, particularly in light of the initial capital investment and continuing maintenance and operational costs. The most realistic approach, therefore, appears to be the initiation of at-source controls which would effect a reduction in the quantities of acid mine drainage emanating from these mine workings.

While benefits of reducing drainage from underground mine workings is illustrated most dramatically in watersheds degraded by acid mine drainage from abandoned underground mines, stream water quality may also be improved significantly by reducing infiltration to active underground mines. Acid mine drainage is generally treated by lime neutralization which increases both the hardness and the total dissolved solids concentration of the product water. Any reduction in the quantity of drainage treated is reflected in the quality of the receiving waters since the smaller volume of discharge is more easily assimilated through dilution.

The state-of-the-art of at-source control is in its infancy and, therefore, is often less effective in practice than it appears to be in theory. A number of schemes have been proposed (and some tested) which attack the problem of controlling drainage prior to contamination. These include methods such as aquifer dewatering, connector wells which transfer water away from toxic strata, surface soil sealants to curb infiltration, surface water diversion, and biologic filters to deaerate infiltrating water. While each of these experimental techniques may potentially be implemented successfully on a site specific basis, they are quite limited in their adaptability because of physical conditions such as the geologic and hydrologic character of the site.

The widespread occurrence of acid mine drainage throughout much of northern Appalachia requires simplified abatement techniques that can be applied over a broad range of geologic and physical geographic settings. The study described within this report defines the methodology and results of one such approach to the reduction of environmental degradation from both surface and underground coal mining operations.

The basis of this report stems from a cooperative and quite comprehensive reclamation and mine drainage abatement program conducted in the Dents Run watershed in Monongalia County, West Virginia, near the city of Morgantown. The objective of the project was to conduct a full-scale demonstration program which documented the effectiveness of reclaiming abandoned surface mined areas in order to reduce surface water infiltration to adjacent underground workings, thereby reducing the amount of acid mine drainage generated from mines nearby. As part of a cooperative agreement, Consolidation Coal Company participated in the abatement efforts throughout the study period by constructing several systems for the treatment of drainage from their active underground mining operations and by taking steps to clean up a refuse disposal area. The overwhelming results of this total watershed clean-up program was the demonstration of a viable mine drainage abatement scheme that has widespread applicability throughout Appalachia.

SECTION 2

CONCLUSIONS

Based upon data collected and analyzed during this demonstration project, the following conclusions were formulated:

- The cooperative effort of government and industry has resulted in nearly complete control of the mine drainage pollution which was discharged to the Dents Run watershed at the onset of this project.

- The combination of surface mine reclamation and treatment of borehole drainage from the active underground mining complex resulted in a 99 percent reduction in the level of acidity and iron concentrations in Dents Run.

- Selective regrading reclamation techniques can be successfully employed to reduce water infiltration where surface mining operations have intercepted underground mine workings.

- Prior to the project, Consolidation Coal Company's pumping rates were influenced considerably on a daily basis by regional rainfall and a substantial portion of the discharge from their active workings came from the diversion of surface water into underground operations through unreclaimed surface mines.

- The volume of water discharged from abandoned underground workings within the watershed was relatively insignificant, with the exception of mine opening 38 in Section G (refer to Figure 12). Surface reclamation techniques employed during this project appeared to reduce this volume of drainage, although flow monitoring data was not sufficiently detailed to substantiate this suspicion.

- Over 40 hectares (100 acres) of orphaned surface mined land was regraded and revegetated during this project. Unfortunately, inadequate post-reclamation maintenace has resulted in sparse vegetative cover and development of erosion gullies.

- Weirs constructed to accommodate continuous stream flow measurements were extremely costly and a constant source of problems due to siltation and flooding. Parshall flumes are much more suitable to this type of application.

- By comparing borehole pumping rates before and after reclamation efforts for periods of near-equal rainfall, it appears that there was a substantial reduction in infiltration (30 percent) following the mine sealing reclamation.

- The incremental cost of reclamation using compaction sealing (Priority I reclamation sites) was approximately $140 per hectare ($50/A) - about 4 percent over conventional reclamation techniques as employed in Priority II reclamation mine sites.

- With the increased emphasis placed on reclamation of abandoned surface mines through the Federal Surface Mining Control and Reclamation Act of 1977, it appears from this demonstration program that this type of reclamation may be employed wherever physical conditions permit.

SECTION 3

RECOMMENDATIONS

Based upon the findings and conclusions of this demonstration project, the following recommendations are made:

- Reclamation projects of this nature should incorporate a routine maintenance program to assure the continued success of vegetative cover and minimize degradation of the site by erosion and/or sedimentation.
- Similar reclamation schemes should be implemented by the appropriate state or federal agencies in areas of comparable geologic and/or mining character. This recommendation is based on the success of the Dents Run demonstration program and the limited state-of-the-art of underground mine sealing technology.
- State and federal reclamation agencies should develop inventories of the mine sites where selective reclamation techniques (such as those demonstrated in this study) can be employed to reduce infiltration into underground mine workings. By so doing, the responsible government regulatory agency could work with cooperating mine operators to modify reclamation practices in order to obtain maximum benefit on ongoing reclamation efforts.
- Future demonstration programs should carefully evaluate data requirements to avoid extraneous data collection and needless equipment maintenance.
- Access to reclamation sites should be controlled to prevent degradation of the site by dumping of trash and debris, grazing of livestock, and/or disruption of water drainage systems by rutting from vehicular traffic.

SECTION 4

BACKGROUND INFORMATION

This project was initiated in the Spring of 1971 and was originally intended to be a three and one-half year study. The first phase, a feasiblity analysis, was slated to be completed within six months; subsequent phases - design engineering, reclamation, and monitoring station construction - were to take about one and one-half years; monitoring was to continue through the entire program and include one year of post-reclamation monitoring. The report phase was to be completed during a two to three month period ending in the fall of 1974.

Due to the extended time frame over which the study was in progress, a number of unfortunate events occurred which had a direct bearing on the systematic completion of these various tasks. More importantly, modifications to the water handling system within Consolidation Coal Company's Osage and Arkwright mine workings, combined with monitoring equipment malfunctions, created severe problems with data interpretation and analysis. The complexity of these problems in relationship to their chronological occurrence precludes a simplified explanation without a thorough understanding of their historical development. These events and their relevance to the overall demonstration program will be discussed in detail throughout the body of this report.

In order to appreciate the overall success of this demonstration program and the impact of certain unpredicted events, it is first necessary to fully understand the objectives of the project and the physical features influencing the reclamation approach.

PHYSICAL CONDITIONS

The Dents Run watershed is located in Monongalia County, West Virginia, and is part of the Monongahela River Basin (See Figure 1). The U.S. Geological Survey 7.5 minute topographic quadrangle maps which describe the site are: (1) Osage, West Virginia; (2) Riversville, West Virginia; (3) Morgantown North, West Virginia; (4) Morgantown South,

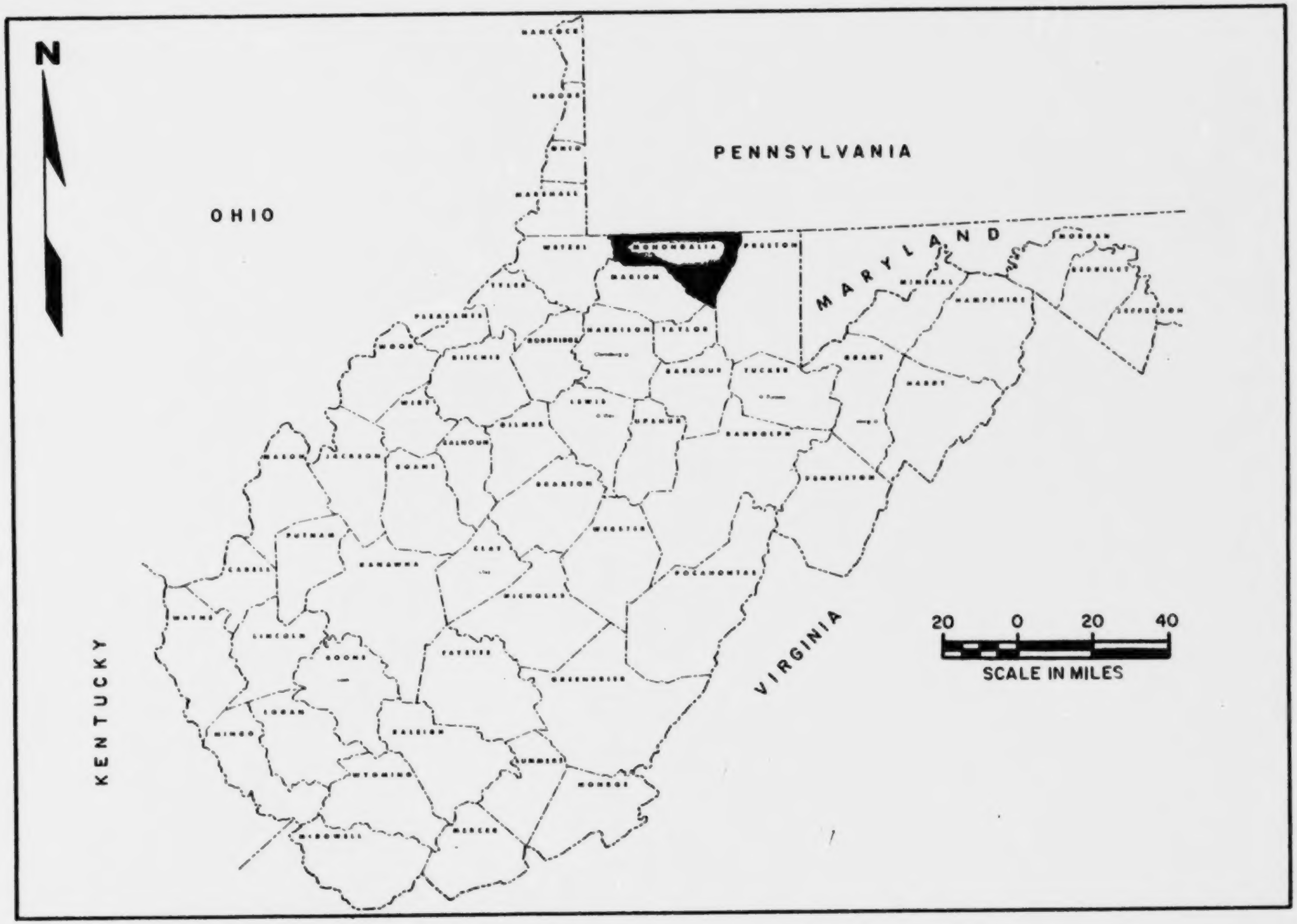

N
OHIO
PENNSYLVANIA
MARYLAND
VIRGINIA
KENTUCKY
MONONGALIA
20
0
20
40
SCALE IN MILES

Figure 1. County location map.

West Virginia (See Figure 2). The watershed has an area of 37.8 square kilometers (14.6 square miles) with the main axis being in a generally east-west direction. Along its southern boundary, the watershed is traversed by U.S. Route 19, which follows the course of Dents Run from a point opposite Morgan Heights then west to Laurel Point. Interstate Highway 79 crosses Dents Run at the eastern end in a north-south direction.

The terrain of the eastern part of the watershed can generally be described as rugged by virtue of numerous deep and narrow valleys; the western portion has a more subdued topography and can generally be described as rolling. The elevation of the highest peak in the watershed is approximately 488 meters (1,600 feet), while the valley floor in the vicinity of Laurel Point is 291 meters (956 feet) with a base of 253 meters (830 feet) at the mouth of Dents Run. Located in the Allegheny Mountains section, the watershed is part of the Appalachian Plateau's physiographic province. The mountain tops are forested, while the valley sides and bottom are open grassland and farmland. Dents Run flows from west to east and enters the Monongahela River at the city of Granville, which is due west of the city of Morgantown.

Aerial photographs were taken of the area during September of 1971. A photographic mosaic of the area is illustrated in Figure 3.

The Dents Run watershed is underlain principally by sedimentary rocks of the Pennsylvanian age. The principal coal, oil, and gas development in this area has been in the Monongahela Group, which is comprised of the youngest rocks of the Pennsylvanian age and is typically composed of cyclic sequences of sandstone, siltstone, red and grey shale, limestone, and four (4) economically important coal seams. The most prominent and commercially developed coals in the watershed are the Pittsburgh, Redstone, Sewickley, and Waynesburg seams. These coal seams outcrop along the valley sides beginning at the mouth of Dents Run near Granville. The lowest of these is the Pittsburgh seam. The Redstone seam is approximately 107 to 114 meters (350 to 375 feet) above the Pittsburgh seam. The Pittsburgh seam and all others above it dip to the west. The elevation of the Pittsburgh seam is approximately 305 meters (1,000 feet) at Granville and about 229 meters (750 feet) in the western section of the watershed near Sugar Grove. The valley floor elevation at Sugar Grove is approximately 335 meters (1,100 feet) so the Pittsburgh seam is 107 meters (350 feet) below the valley floor at this point. A typical cross-section of the watershed is depicted in Figure 4.

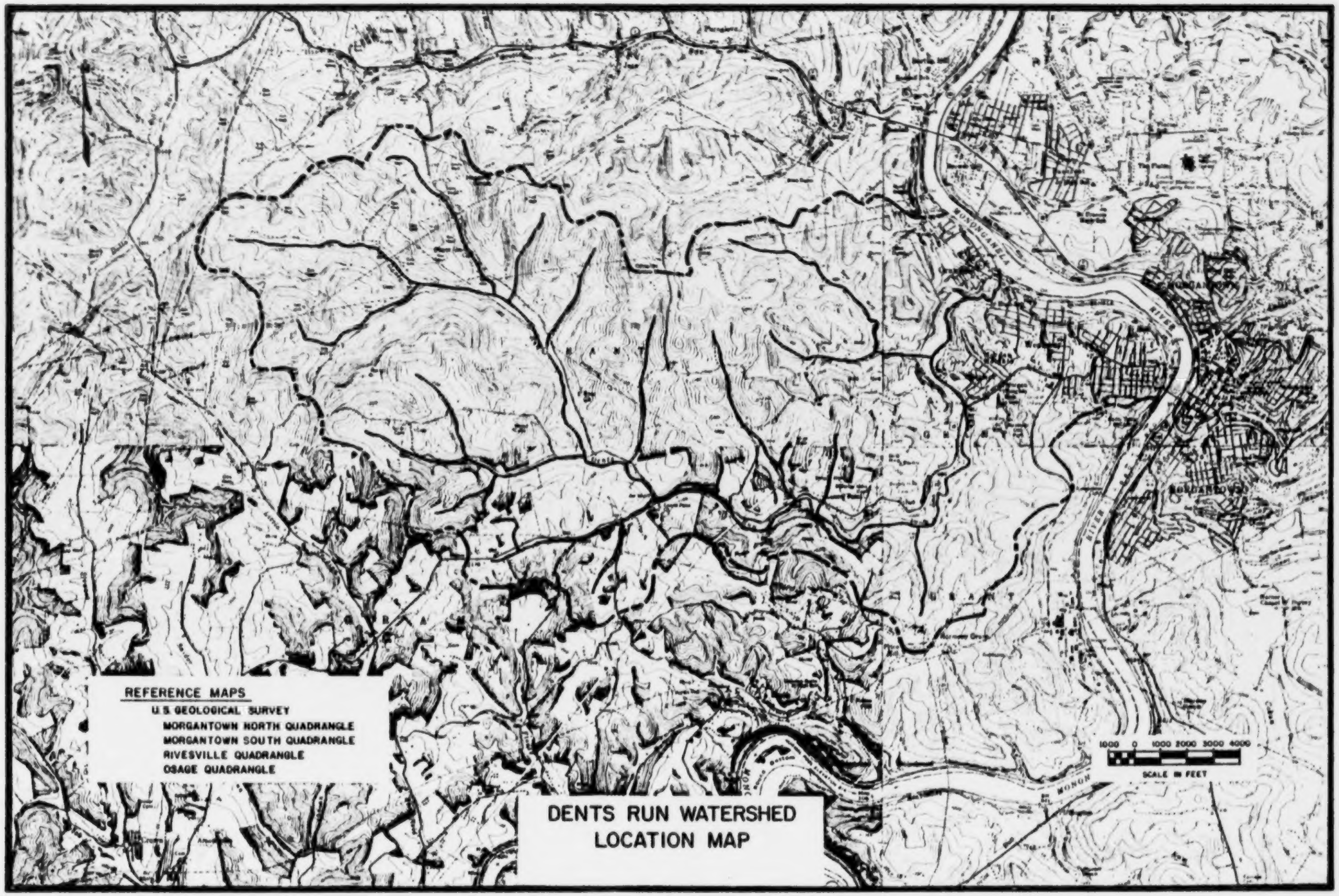
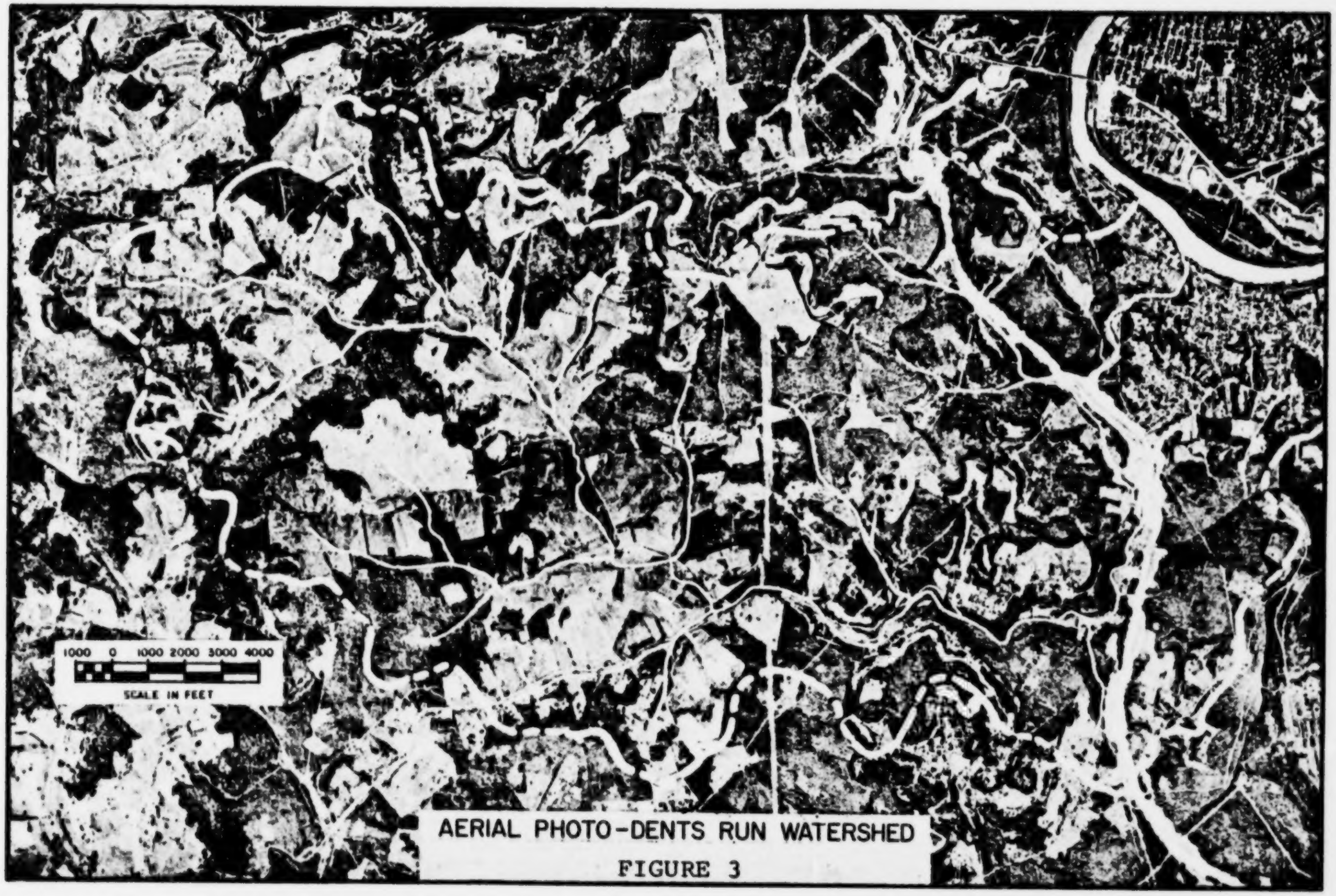

DENTS RUN WATERSHED
LOCATION MAP
REFERENCE MAPS
U.S. GEOLOGICAL SURVEY
MORGANTOWN NORTH QUADRANGLE
MORGANTOWN SOUTH QUADRANGLE
RIVESVILLE QUADRANGLE
OSAGE QUADRANGLE
1000 0 1000 2000 3000 4000
SCALE IN FEET
MONONGAHELA
RIVER

Figure 2. Dents Run watershed location map.


1000 0 1000 2000 3000 4000
SCALE IN FEET

AERIAL PHOTO-DENTS RUN WATERSHED
FIGURE 3

Figure 3. Aerial photo - Dents Run watershed.

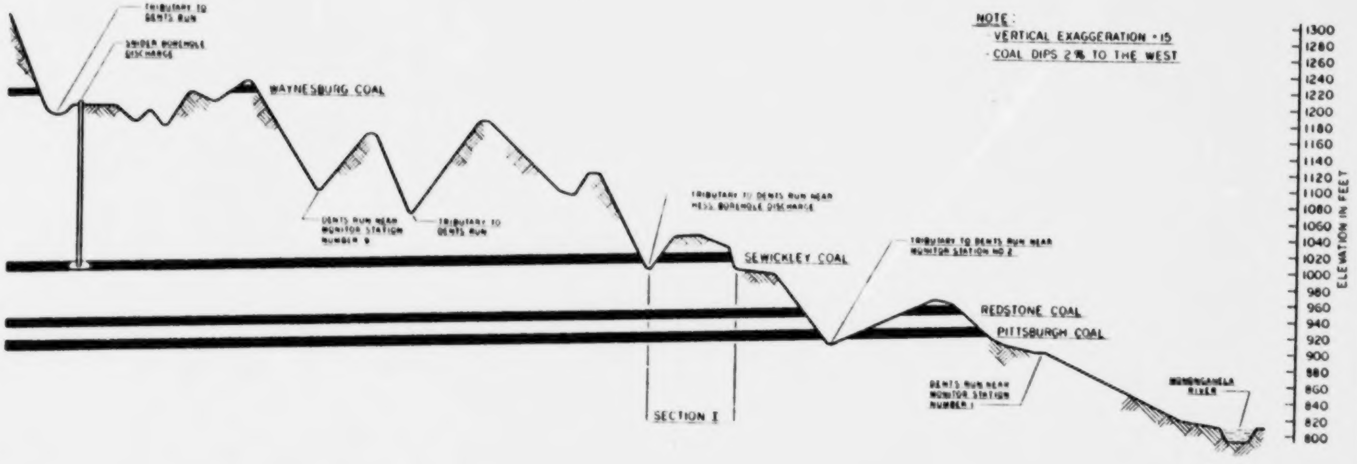

TRIBUTARY TO DENTS RUN
SNIDER BOREHOLE DISCHARGE
WAYNESBURG COAL
DENTS RUN NEAR MONITOR STATION NUMBER 9
TRIBUTARY TO DENTS RUN
TRIBUTARY TO DENTS RUN NEAR HESS BOREHOLE DISCHARGE
SEWICKLEY COAL
SECTION I
TRIBUTARY TO DENTS RUN NEAR MONITOR STATION NO 2
REDSTONE COAL
PITTSBURGH COAL
DENTS RUN NEAR MONITOR STATION NUMBER 1
MONONGAHELA RIVER
NOTE:
- VERTICAL EXAGGERATION = 15
- COAL DIPS 2% TO THE WEST
1300
1280
1260
1240
1220
1200
1180
1160
1140
1120
1100
1080
1060
1040
1020
1000
980
960
940
920
900
880
860
840
820
800
ELEVATION IN FEET

Figure 4. Typical cross section - Dents Run watershed.

Surface mining of the Pittsburgh-Redstone-Sewickley seams is thus confined largely to the eastern end of the Dents Run watershed with surface mining of the Waynesburg outcrop occurring near the hilltops throughout the watershed. The only drift mining noted in the Waynesburg seam occurs in isolated tracts in the extreme western portions of the watershed, although the Redstone and the Sewickley seam have been drift mined extensively in the eastern end of the watershed for many years. Surface mining of the Redstone and Sewickley outcrops has also occurred in the eastern end of the watershed, but was substantially completed prior to 1952. Additional surface mining of these seams took place between 1960 and 1966. Since 1966, surface mining has occurred in the Waynesburgh seam, particularly in the area around Chisler's Knob.

Most of the unreclaimed surface disturbance occurs in the eastern portion of the watershed. Water that entered the subsurface water system as a result of numerous drift mine interceptions located in the unreclaimed areas eventually drained into the Pittsburgh seam. The original premise of the project was that surface reclamation techniques could be employed to backfill the surface mine pits, cover the exposed seam, and seal the exposed drift mine entries or interceptions in order to reduce the surface water entry into the subsurface water system. The intercepted runoff would be channeled to the normal surface drainage courses in the watershed.

At the onset of this project, the Consolidation Coal Company maintained six active borehole discharges within the watershed (see Figure 5). Five of the six boreholes discharged water from active or inactive underground mine workings within the Pittsburgh coal seam. These pumps were located within the mine; two of these, the Valotto and the Laurel Point, were constant discharge pumps. The Hess, Six Right, and Loar pumps were float controlled. Surface water intercepted by abandoned unreclaimed mining operations in the eastern portion of the watershed drained to the Hess discharge point and then continued on to Laurel Point. The Laurel Point pumping facilities handled a small portion of this drainage while the excess continued on to either the Loar or Six Right discharge points. A typical section of this area is illustrated in Figure 6.

The sixth borehole, Snider, discharged water from the abandoned workings of the Brock mine which is located in the Sewickley coal seam. The Snider discharge represented the largest single discharge within the watershed with an average daily pumping rate ranging between 1,140 cubic meters (0.3 million gallons) in the later summer to 13,200 cubic meters (3.5 million gallons) during the winter and spring months.

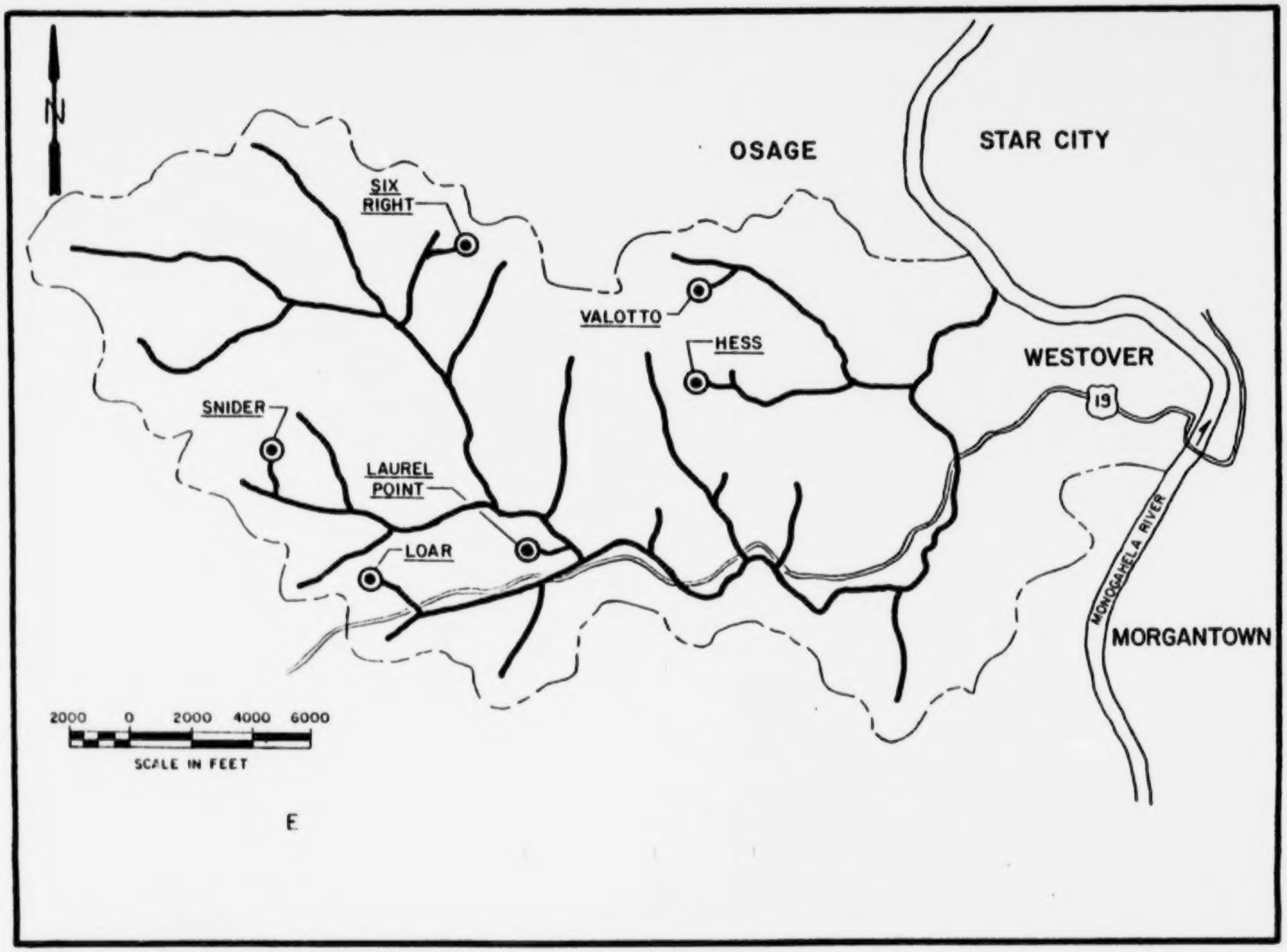

N
OSAGE
STAR CITY
SIX RIGHT
VALOTTO
HESS
WESTOVER
19
SNIDER
LAUREL POINT
LOAR
MONONGAHELA RIVER
MORGANTOWN
2000 0 2000 4000 6000
SCALE IN FEET
E

Figure 5. Borehole locations.

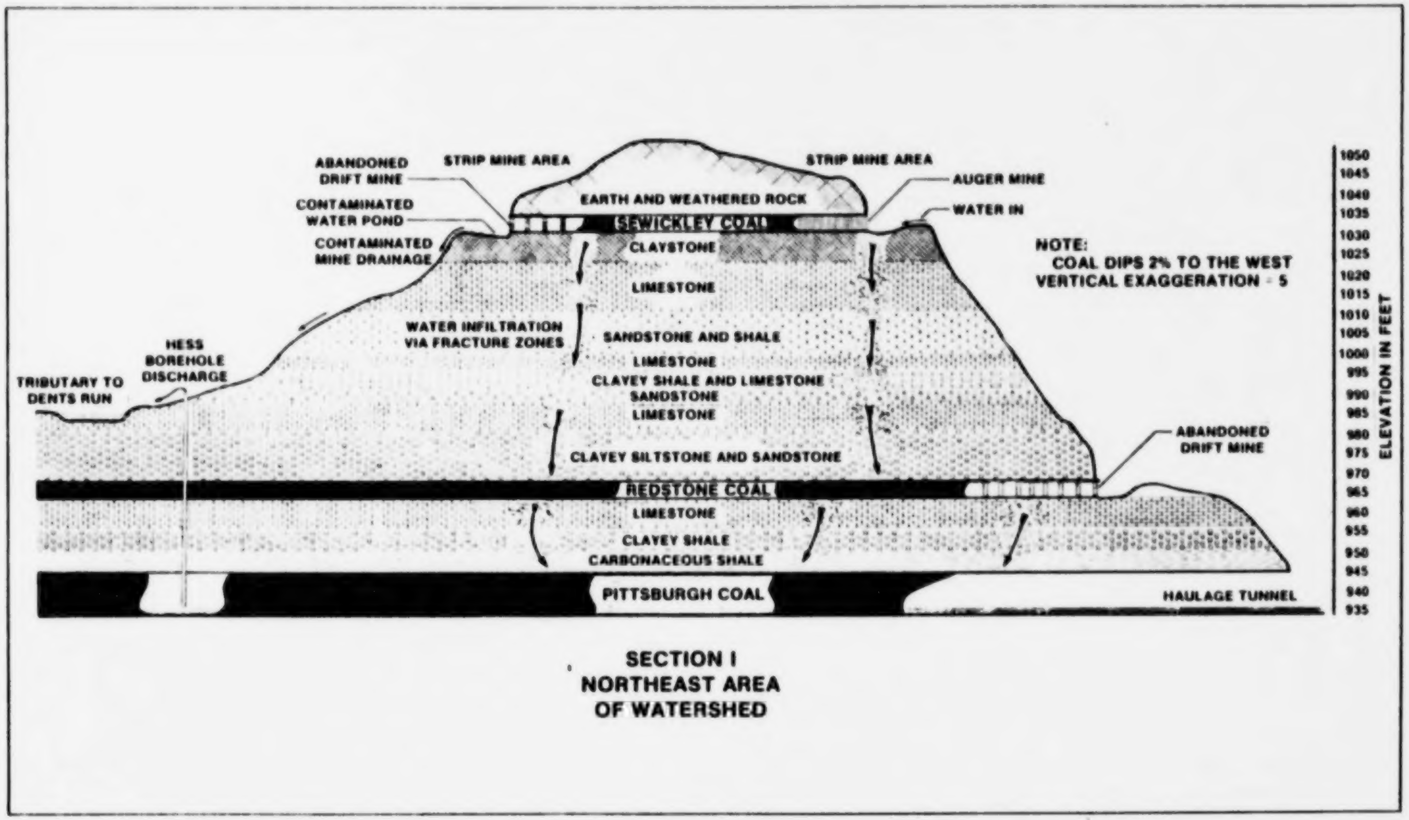

ABANDONED DRIFT MINE
STRIP MINE AREA
STRIP MINE AREA
AUGER MINE
CONTAMINATED WATER POND
EARTH AND WEATHERED ROCK
WATER IN
SEWICKLEY COAL
CONTAMINATED MINE DRAINAGE
CLAYSTONE
NOTE:
COAL DIPS 2% TO THE WEST
VERTICAL EXAGGERATION - 5
LIMESTONE
WATER INFILTRATION VIA FRACTURE ZONES
SANDSTONE AND SHALE
HESS BOREHOLE DISCHARGE
LIMESTONE
TRIBUTARY TO DENTS RUN
CLAYEY SHALE AND LIMESTONE
SANDSTONE
LIMESTONE
ABANDONED DRIFT MINE
CLAYEY SILTSTONE AND SANDSTONE
REDSTONE COAL
LIMESTONE
CLAYEY SHALE
CARBONACEOUS SHALE
PITTSBURGH COAL
HAULAGE TUNNEL
1050
1045
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
990
985
980
975
970
965
960
955
950
945
940
935
ELEVATION IN FEET
SECTION I
NORTHEAST AREA
OF WATERSHED

Figure 6. Section I northeast area of watershed.

The Snider borehole employed a float controlled surface pump; accurate pumping records were available for the Snider discharge since 1966 and can be correlated against recorded rainfall data for this same period. Figure 7 graphically illustrates the correlation between precipitation and pumping rates at the Snider borehole discharge during this period (1966 through 1971).

Typically, water discharged from the Sewickley coal seam is alkaline in nature. When acid water did appear at the Snider borehole, it was thought to have come from a flooded abandoned mine in the Pittsburgh seam. When the abandoned mine flooded, water was forced upward into the Sewickley seam through abandoned boreholes and fracture zones. Drainage accumulated in a swag at the Snider borehole location and was pumped to the surface to prevent overflow of the swag with consequent flooding into the Arkwright mine shaft and Pittsburgh coal workings (Figure 8). Although this portion of the Arkwright mine was inactive with no prospects of reopening, the seals between the inactive and active portions of the mine were not adequate to permit flooding of the inactive section without affecting active operations.

WATER RESOURCES

The Dents Run watershed drains an area which is characterized by a heavy concentration of surface mines, drift mines, refuse dumps, and spoil banks which contribute significantly to the acid mine drainage problems.

Waters were sampled at various locations throughout the watershed and were found, in most instances, to be acidic and exhibited significant concentrations of iron, sulfate, and dissolved solids, as well as high specific conductance. Such concentrations, in most cases, were beyond criteria established for water quality in the Monongahela River and its tributaries as set forth in the West Virginia Administrative Regulations (Series II, Chapter 20, Articles 5 and 5A, Code of West Virginia). The geographic locations of these sample points are illustrated in Figures 9 and 12. The results of these analyses are reported in Tables C-1 through C-39 which appear in Appendix C of this report.

Based upon the volume and quality of the discharges from Consolidation Coal Company alone, there was an average daily discharge of 44 metric tons (48 tons) of sulfate, or 16,060 metric tons (17,500 tons) per year. The Monongahela River at Star City (approximately 1.6 kilometers - 1.0 mile - downriver from the confluence of Dents Run and the Monongahela River) reportedly carried an average sulfate

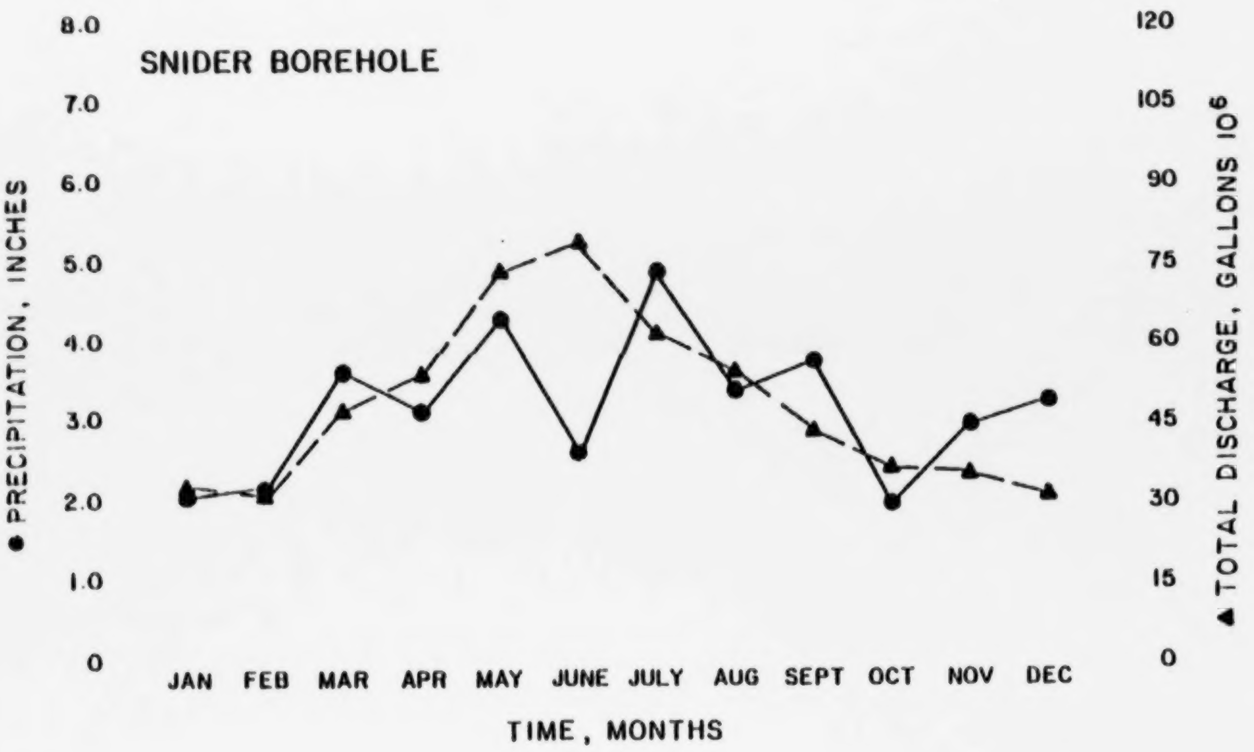


Figure 7. Average precipitation and pumping rate vs. time 1966 through 1971.

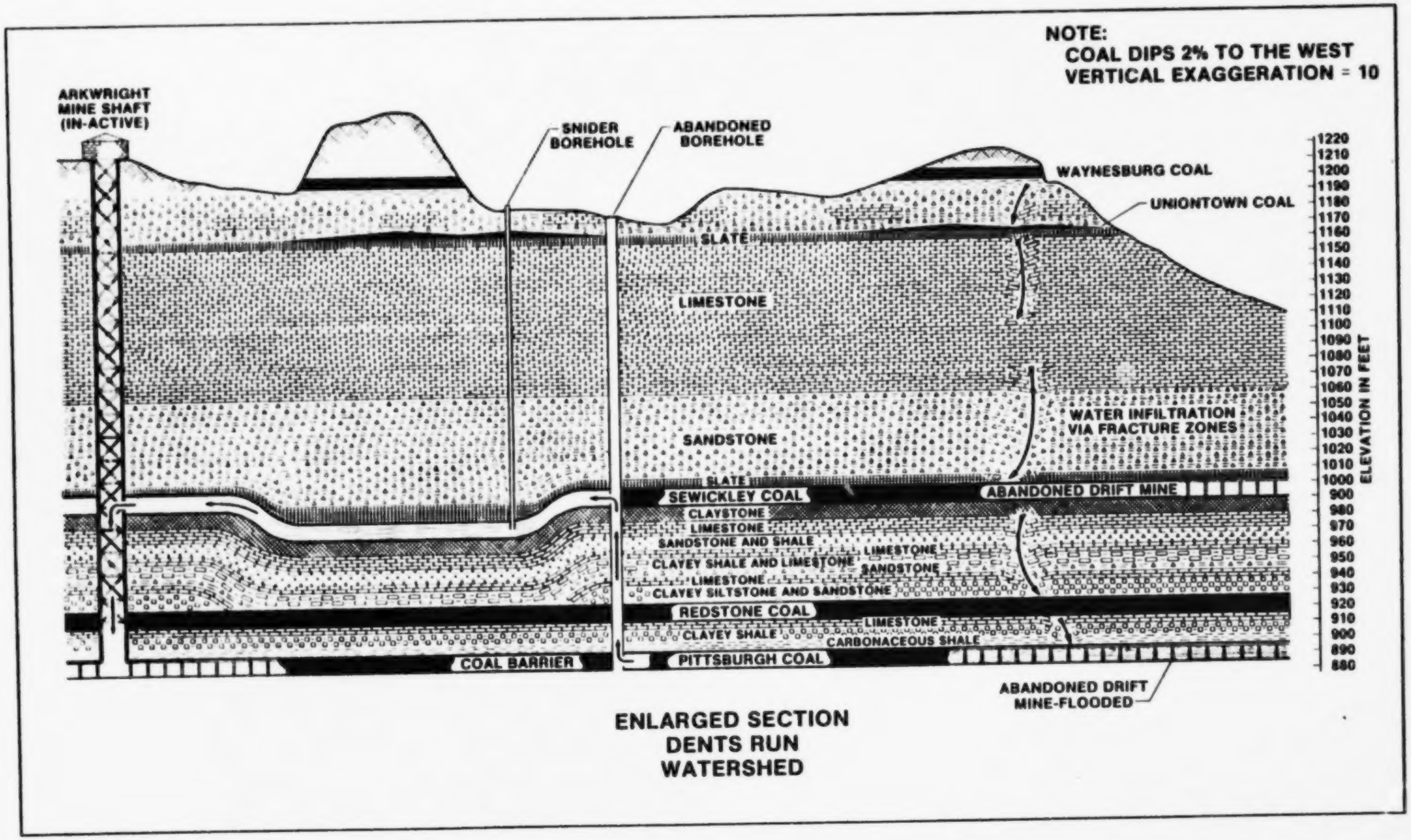
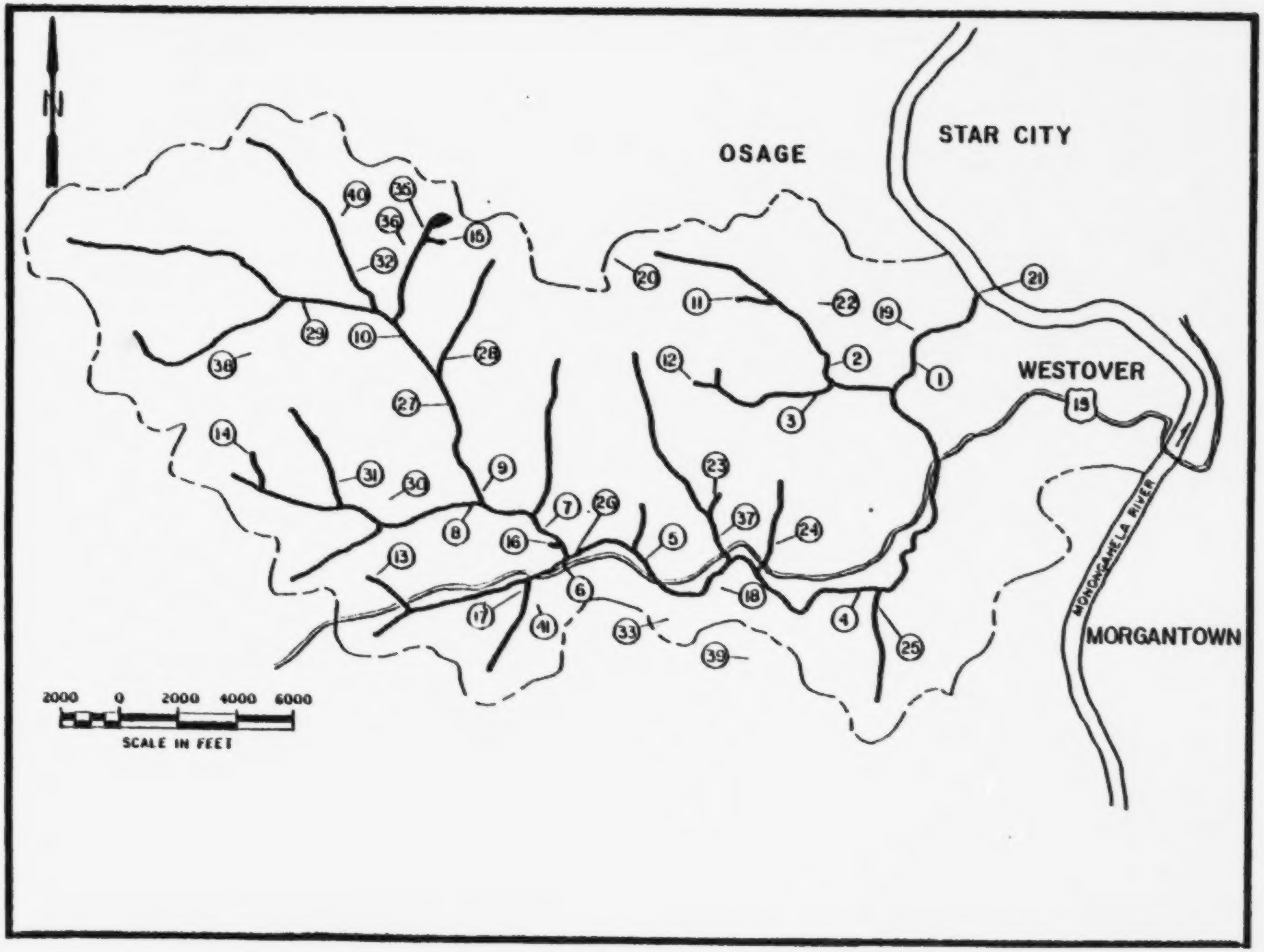

NOTE:
COAL DIPS 2% TO THE WEST
VERTICAL EXAGGERATION = 10
ARKWRIGHT MINE SHAFT (IN-ACTIVE)
SNIDER BOREHOLE
ABANDONED BOREHOLE
WAYNESBURG COAL
UNIONTOWN COAL
SLATE
LIMESTONE
WATER INFILTRATION VIA FRACTURE ZONES
SANDSTONE
SLATE
SEWICKLEY COAL
ABANDONED DRIFT MINE
CLAYSTONE
LIMESTONE
SANDSTONE AND SHALE
LIMESTONE
CLAYEY SHALE AND LIMESTONE
SANDSTONE
LIMESTONE
CLAYEY SILTSTONE AND SANDSTONE
REDSTONE COAL
LIMESTONE
CLAYEY SHALE
CARBONACEOUS SHALE
COAL BARRIER
PITTSBURGH COAL
ABANDONED DRIFT MINE-FLOODED
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
1110
1100
1090
1080
1070
1060
1050
1040
1030
1020
1010
1000
900
980
970
960
950
940
930
920
910
900
890
880
ELEVATION IN FEET
ENLARGED SECTION
DENTS RUN
WATERSHED

Figure 8. Enlarged section - Dents Run watershed.



N
OSAGE
STAR CITY
WESTOVER
19
MORGANTOWN
MONONGAHELA RIVER
40
35
36
15
32
20
11
22
19
21
29
10
38
28
12
2
1
3
27
14
23
31
30
9
7
26
37
24
5
8
16
13
6
18
17
41
33
4
25
39
2000 0 2000 4000 6000
SCALE IN FEET

Figure 9. Dents Run watershed sample point locations.

concentration of 371 ppm or 1,145 metric tons (1,262 tons) per day, which was twice the load of that measured upriver at Fairmont, West Virginia. The marked increase in load was due to the contribution from tributaries such as Booths Creek, Deckers Creek, Scotts Run, Robinson Run, and Dents Run.

The local streams that are continuously affected by acid mine drainage are identified on the drainage map illustrated in Figure 10.

The investigation of Dents Run and its tributaries verified that the watershed comprises an area of 3,682 hectares (9,097 acres) and contains 38.6 kilometers (24 miles) of streams. This data is tabulated in Tables 1 and 2 and illustrated in Figure 11.

A tabulation of rainfall data from the period 1960 through 1971 is presented in Table 3. This data represents precipitation recorded at the Morgantown FAA airport, which is located approximately 1.6 kilometers (0.1 mile) east of the Dents Run watershed. A recording rain and snow gauge was installed near the center of the watershed to obtain a more accurate appraisal of the actual rainfall within this area. As expected. this data correlated very favorably with rainfall data from the U.S. Weather Bureau Station in Morgantown over the project period. This data is presented in Table 4.

In general, the precipitation during the study period was in excess of the 10 year average for the period 1960-1969 as recorded at the Morgantown airport but was slightly less than the long-term average of 123.77 cm (48.73 inches) recorded from 1931 through 1970.

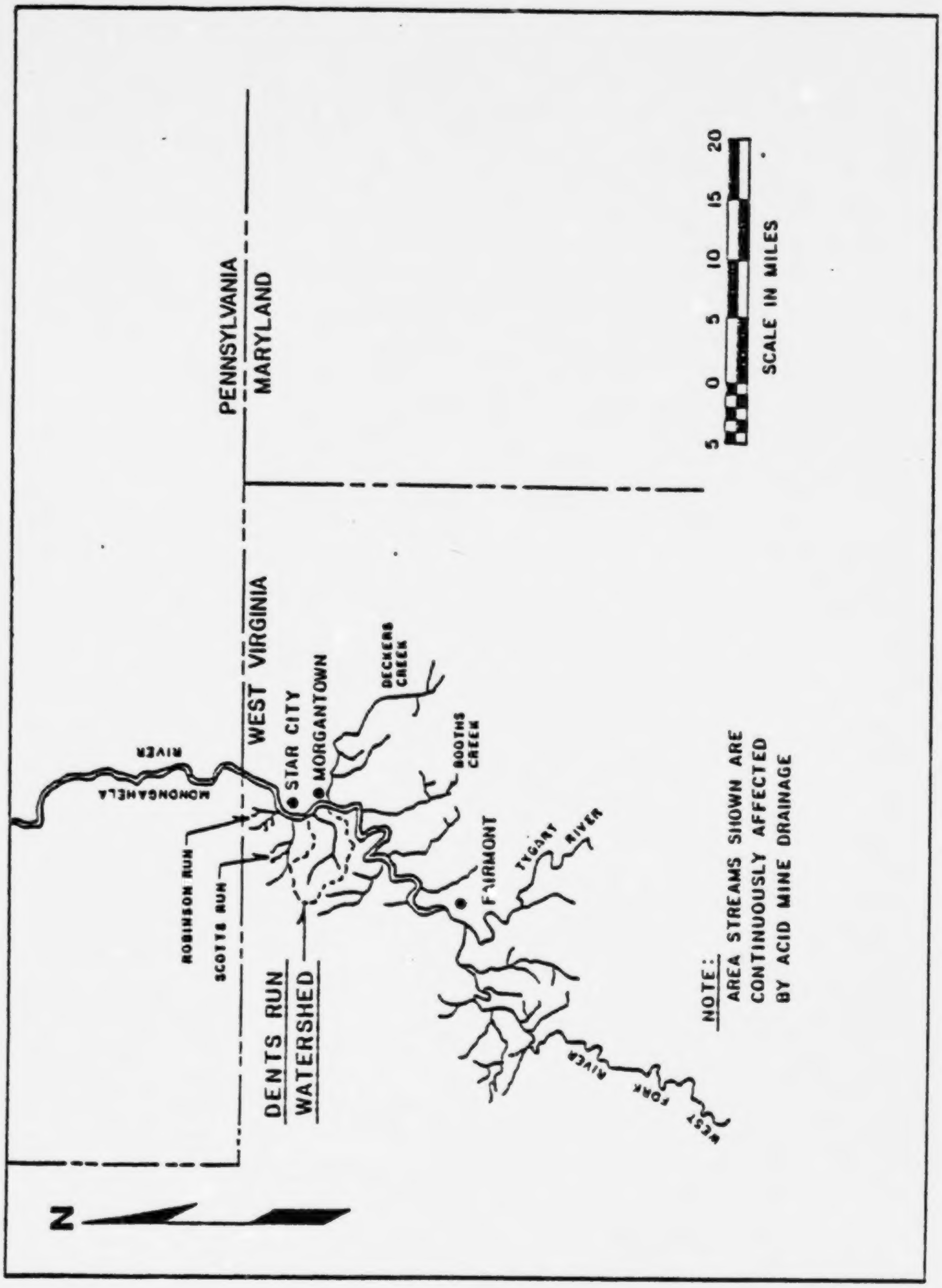

N
MONONGAHELA RIVER
PENNSYLVANIA
MARYLAND
WEST VIRGINIA
STAR CITY
MORGANTOWN
DECKERS CREEK
BOOTHS CREEK
ROBINSON RUN
SCOTTS RUN
DENTS RUN WATERSHED
FAIRMONT
TYGART RIVER
WEST FORK RIVER
NOTE:
AREA STREAMS SHOWN ARE CONTINUOUSLY AFFECTED BY ACID MINE DRAINAGE
5
0
5
10
15
20
SCALE IN MILES

Figure 10. Drainage map.

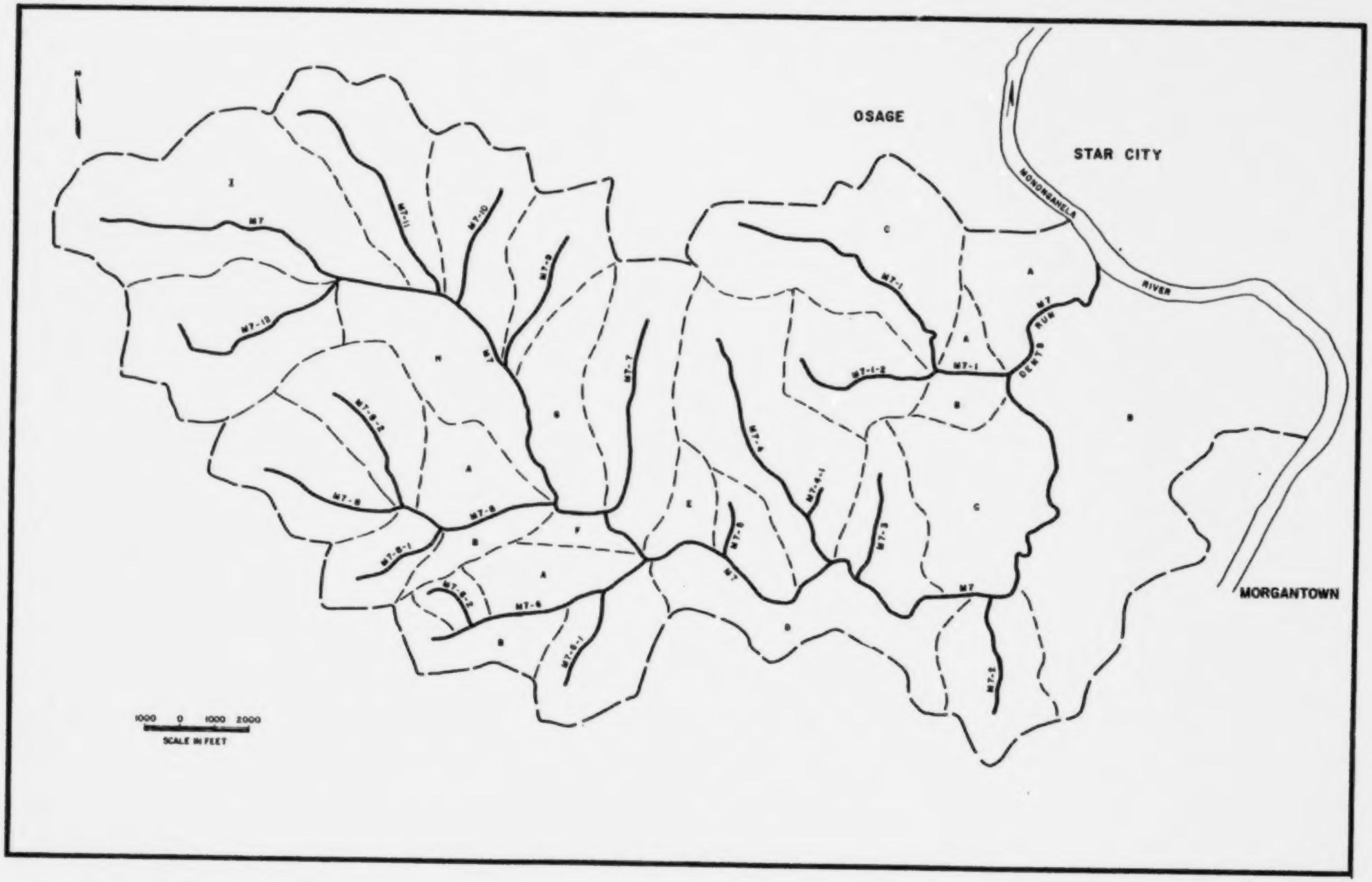

OSAGE
STAR CITY
MONONGAHELA
RIVER
MORGANTOWN
DENTS RUN
M7
M7-1
M7-1-2
M7-2
M7-3
M7-4
M7-4-1
M7-5
M7-6
M7-6-1
M7-6-2
M7-7
M7-8
M7-8-1
M7-8-2
M7-9
M7-10
M7-11
M7-12
A
B
C
D
E
F
G
H
I
1000 0 1000 2000
SCALE IN FEET

Figure 11. Dents Run tributaries and subwatersheds.

TABLE 1. TABULATION OF STREAM LENGTHS

Stream Identification Number	Length Kilometers	 Miles
M7-Dents Run	13.7	8.5
M7-1	3.1	1.9
M7-1-2	1.4	0.9
M7-2	1.1	0.7
M7-3	1.0	0.6
M7-4	2.3	1.4
M7-4-1	0.2	0.1
M7-5	0.5	0.3
M7-6	1.9	1.2
M7-6-1	1.0	0.6
M7-6-2	0.5	0.3
M7-7	1.8	1.1
M7-8	2.6	1.6
M7-8-1	0.2	0.1
M7-8-2	0.8	0.5
M7-8-3	1.1	0.7
M7-9	1.3	0.8
M7-10	1.1	0.7
M7-11	1.9	1.2
M7-12	1.8	1.1
TOTAL LENGTH	39.3	24.3

TABLE 2. TABULATION OF SUBWATERSHED AREAS

Subwatershed Number	Area		Subwatershed Number	Area	
	Hectares	Acres		Hectares	Acres
M7-A	91.6	226.1	M7-5	47.8	118.1
M7-B	514.7	1270.7	M7-6-A	64.4	159.1
M7-C	164.0	405.0	M7-6-B	59.8	147.6
M7-D	142.1	350.8	M7-6-1	99.0	244.3
M7-E	36.1	89.2	M7-6-2	21.9	54.1
M7-F	23.2	57.4	M7-7	160.1	395.2
M7-G	103.6	255.7	M7-8	118.2	291.9
M7-H	127.5	314.8	M7-8-A	69.1	170.5
M7-I	290.2	716.6	M7-8-B	35.8	88.4
M7-1-A	23.9	59.0	M7-8-1	58.4	144.3
M7-1-B	30.6	75.4	M7-8-2	104.9	259.1
M7-1-C	238.4	588.7	M7-9	89.7	221.4
M7-1-2	102.3	252.5	M7-10	115.5	285.3
M7-2	103.0	254.2	M7-11	151.4	373.9
M7-3	85.0	209.9	M7-12	185.2	457.5
M7-4	227.1	560.8	TOTAL	3684.5	9097.5

TABLE 3. TABULATION OF RAINFALL DATA, MORGANTOWN FAA AIRPORT, 1960 THROUGH 1971

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YR. TOT.
1960	2.39	3.29	1.98	1.76	4.97	2.05	4.94	3.59	3.10	2.84	1.40	1.62	33.93
1961	1.41	3.21	5.80	4.42	2.84	6.87	5.58	3.91	4.29	3.00	3.44	3.25	48.02
1962	2.67	3.99	4.15	4.82	1.92	2.21	2.73	3.84	4.10	3.22	3.34	3.15	39.14
1963	1.42	1.62	6.55	1.45	1.36	5.35	1.39	3.41	1.90	0.24	3.92	0.92	29.53
1964	2.14	2.38	3.91	4.66	1.25	4.62	3.91	4.77	3.44	0.86	3.50	4.30	39.74
1965	3.04	1.31	3.42	3.57	1.29	2.27	3.93	3.05	4.62	1.88	1.58	0.61	30.57
1966	3.60	3.32	1.04	4.51	1.47	0.87	3.13	3.77	3.45	1.71	3.83	1.71	32.41
1967	0.61	2.08	7.29	2.92	6.54	1.56	4.23	3.25	3.87	2.60	2.91	3.11	40.97
1968	1.95	0.63	4.11	1.84	7.47	2.88	2.10	3.84	3.09	1.77	3.65	2.91	36.24
1969	1.56	0.82	1.76	3.43	2.67	2.37	8.71	2.23	2.05	1.47	2.43	4.44	33.94
1970	1.63	1.84	4.54	4.81	2.59	4.26	4.91	3.36	3.69	3.15	1.86	5.31	41.95
1971	2.84	4.08	2.80	1.14	4.86	3.63	6.20	3.60	6.42	1.14	3.25	2.09	42.05
TOT.	25.26	28.57	47.35	39.33	39.23	38.94	51.76	41.62	44.02	23.88	35.11	33.42	448.49
AVE.	2.11	2.38	3.95	3.28	3.27	3.25	4.31	3.47	3.67	1.99	2.93	2.79	37.37

TABLE 4. MONTHLY PRECIPITATION DATA FOR PROJECT PERIOD, RAINFALL cm (inches)

Month	1970	1971	1972	1973	1974
January	4.14 (1.63)	7.21 (2.84)	10.67 (4.2)	4.06 (1.6)	10.67 (4.2)
February	4.67 (1.84)	10.36 (4.08)	8.64 (3.4)	5.08 (2.0)	11.18 (4.4)
March	11.53 (4.54)	7.11 (2.80)	10.67 (4.2)	4.57 (1.8)	14.22 (5.6)
April	12.22 (4.81)	2.90 (1.14)	14.73 (5.8)	13.21 (5.2)	8.64 (3.4)
May	6.58 (2.59)	12.3 (4.86)	7.11 (2.8)	9.40 (3.7)	13.46 (5.3)
June	10.82 (4.26)	9.22 (3.63)	23.37 (9.2)	6.10 (2.4)	15.49 (6.1)
July	12.47 (4.91)	15.75 (6.20)	6.60 (2.6)	10.67 (4.2)	9.40 (3.7)
August	8.53 (3.36)	9.14 (3.60)	8.13 (3.2)	9.40 (3.7)	9.65 (3.8)
September	9.37 (3.69)	16.31 (6.42)	5.84 (2.3)	7.62 (3.0)	14.48 (5.7)
October	8.00 (3.15)	2.90 (1.14)	7.11 (2.8)	7.01 (2.76)	3.56 (1.4)
November	4.72 (1.86)	8.26 (3.25)	11.94 (4.7)	9.07 (3.52)	5.84 (2.3)
December	13.49 (5.31)	5.31 (2.09)	14.48 (5.7)	13.66 (5.38)	9.65 (3.8)
Yearly Total	106.54 (41.95)	95.70 (42.05)	129.29 (50.9)	99.85 (39.26)	126.24 (49.7)

SECTION 5

PROJECT APPROACH

The study was initiated on the premise that surface water runoff was channelled into underground mine workings through unreclaimed surface mines in the eastern portion of the watershed.

As previously stated, the objective of this comprehensive mine drainage abatement program was to demonstrate the effective reduction of pollution from acid mine drainage through surface water infiltration control. This was to be accomplished by selectively employing specialized reclamation techniques at those abandoned surface mines identified as contributing significantly to infiltration.

Naturally, the first and most important step in such an effort is to determine where interconnections exist between underground workings and the surface. This investigative analysis was initiated early in the study and continued throughout the fall and winter of 1971. Each surface mine area, underground mine opening, and refuse bank was located (Figure 12) and evaluated as to its pollution potential and/or its potential to contribute to the underground mine water volume.

The information presented in the following subsection - Site Characterizations - includes a detailed physical description of each surface mine area and mine opening in the project area, as well as the original recommendations for reclamation work required at each site to facilitate proper execution of the project. The descriptions define the condition of the site as it appeared during the investigative portion of the study. Later sections will discuss reclamation projects actually completed and the current status of these sites.

Each surface mine area and/or mine opening presented is first listed under the section letter of the area of the watershed map in which it is located. The heading identifying and describing the particular surface mine, refuse disposal area, or mine opening and its priority classification then

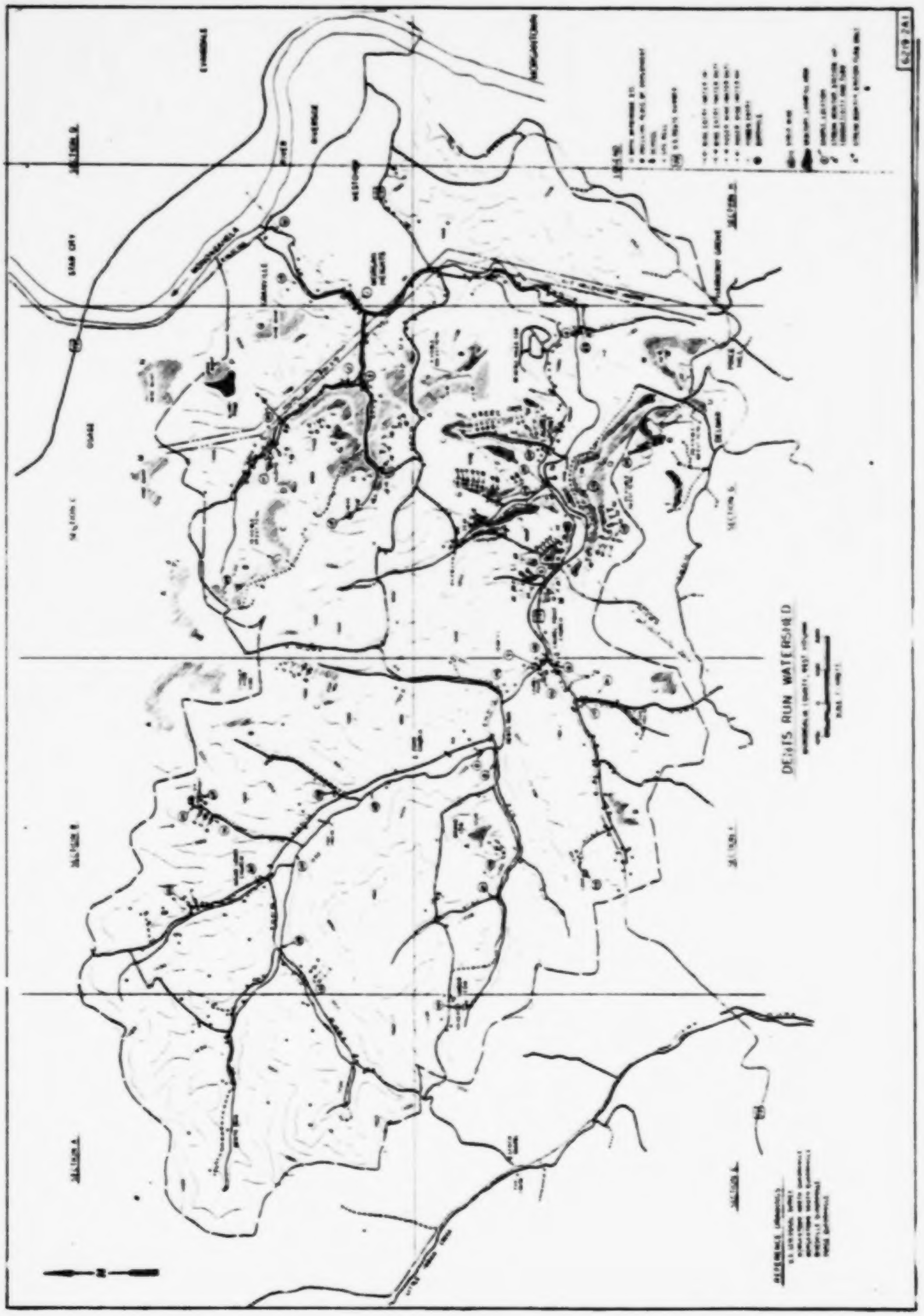

DENTS RUN WATERSHED

Figure 12. Dents Run watershed.

precedes the description concerning that site. The probable coal seam is identified in parentheses immediately below this heading. Letters are used to designate surface mine and refuse disposal areas which correspond with matching lettered cross-hatched areas on the watershed map. Mine openings are identified by number and correspond to matching numbered symbols, in accordance with the legend.

A priority listing was then developed for the work to be performed. Since the objective of this demonstration project was the reduction of mine water pollution through water infiltration control, first priority items refer to those areas which contributed significant amounts of drainage to the underground mine workings, while second priority items are those which contributed directly to stream pollution as a result of surface water runoff. Third priority items are those areas which contributed to aesthetic pollution; this includes all of the sites within the watershed which are not included in the first or second priority listing. The priority listings were as follows:

Priority I - Areas of High Infiltration

1. Dents Run - Suspected Loss of Flow
2. Section G, Strip Area R
3. Section G, Strip Area A
4. Section C, Strip Area C
5. Section G, Strip Area J
6. Borehole - Interception(s)

Priority II - Surface Water Pollution

1. Section G, Strip Area G
2. Section G, Mine Dump N
3. Section C, Strip Areas J and H
4. Section G, Strip Areas D and E
5. Section G, Strip Area M
6. Section G, Strip Area C
7. Section F, Strip Area A
8. Section C, Strip Area S
9. Section G, Strip Areas P and Q
10. Section G, Strip Area B
11. Section C, Strip Area B

Priority III - Aesthetic Pollution

All remaining sites in the watershed.

Items 1 and 6 under Priority I require further explanation, as they are not discussed in the site descriptions. Throughout the investigative portion of this study, significant reductions were observed in the flows measured between sample points 4 and 5 in Dents Run. Subsequent investigations narrowed this apparent water loss to one general area just west of the village of Laurel Point. The Pittsburgh coal seam outcrops in this area and it was theorized that a portion of the stream flow was finding its way into mine workings through fissures or fracture zones present in the streambed. Figure 13 shows the extent of mining in the Pittsburgh coal seam in this area and the proximity of the mining to the streambed. Although subsequent extensive investigations conducted during May and June 1972 failed to substantiate this water loss, it appears in the previous priority listing merely to illustrate the historical progression of events and to demonstrate the research effort devoted to exploring these possible water infiltration points.

Christopher Coal Division personnel believed that a flooded abandoned mine in the Pittsburgh coal seam was the source of some of the mine drainage that was discharging from the Snider borehole. It was felt that water from this mine was finding its way through abandoned boreholes and discharging into the Brock Mine in the Sewickley coal seam. The Snider borehole employed protective pumping to prevent water from building up and flowing into the Arkwright mine shaft and active Pittsburgh mine workings. Figure 8 illustrates the theoretical substrata configuration and origin of subsurface water at the Snider borehole location. The suspected boreholes are believed to be in Section H (refer to Figure 12) near the village of Harmony Grove. Although further investigations seemed to confirm this theory of interceptions, it was impossible to locate any of these boreholes since they were uncharted and had long since been abandonded.

The various types of backfill methods employed in West Virginia throughout the investigative and reclamation portions of this project are illustrated in Figure 14-A, B, C, and 15-A and B. Reclamation work was primarily concerned with pasture type backfills since the project objective was infiltration control rather than aesthetic beneficiation, although several contour backfills were also completed. The backfills were all compacted in the vicinity of the highwall in order to prevent excessive infiltration through the porous spoil material and into intercepted deep mine workings.

Figure 15-C shows a typical application of one surface reclamation technique. The compacted pasture backfill and surface water diversion ditch serve both to reduce further

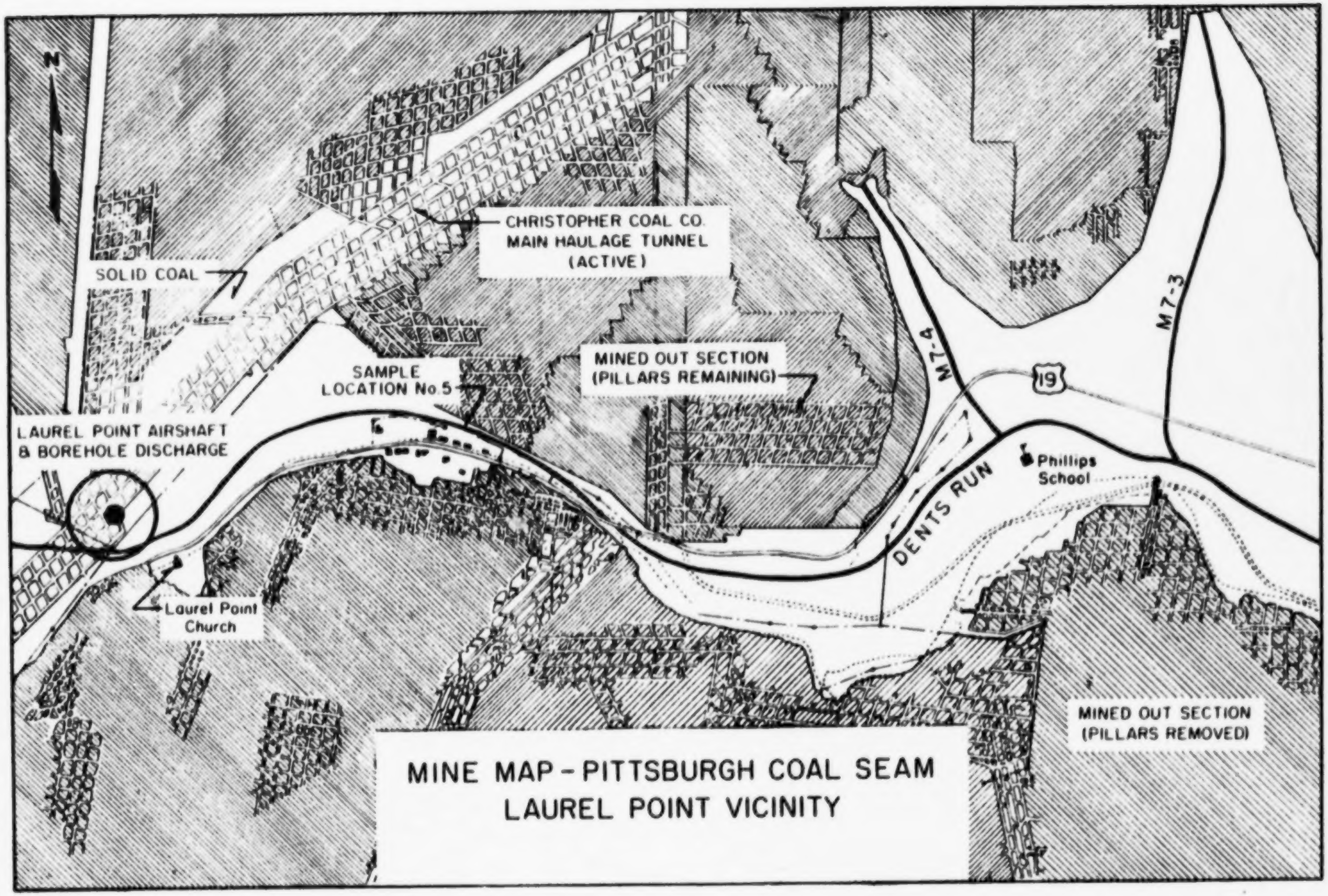

N
SOLID COAL
CHRISTOPHER COAL CO. MAIN HAULAGE TUNNEL (ACTIVE)
MINED OUT SECTION (PILLARS REMAINING)
SAMPLE LOCATION No. 5
LAUREL POINT AIRSHAFT & BOREHOLE DISCHARGE
Laurel Point Church
M7-4
M7-3
19
Phillips School
DENTS RUN
MINED OUT SECTION (PILLARS REMOVED)
MINE MAP - PITTSBURGH COAL SEAM
LAUREL POINT VICINITY

Figure 13. Mine map - Pittsburgh coal seam, Laurel Point vicinity.

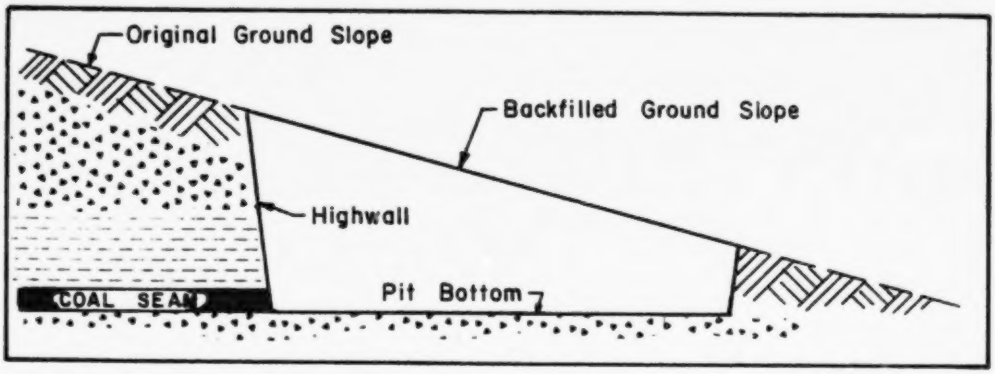

Original Ground Slope
Backfilled Ground Slope
Highwall
COAL SEAM
Pit Bottom

Figure 14-A. Typical contour backfill.

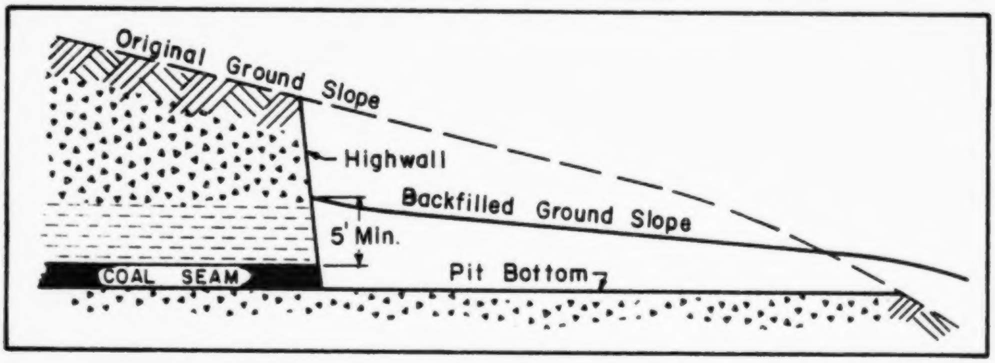

Original Ground Slope
Highwall
Backfilled Ground Slope
5' Min.
COAL SEAM
Pit Bottom

Figure 14-B. Typical pasture backfill.

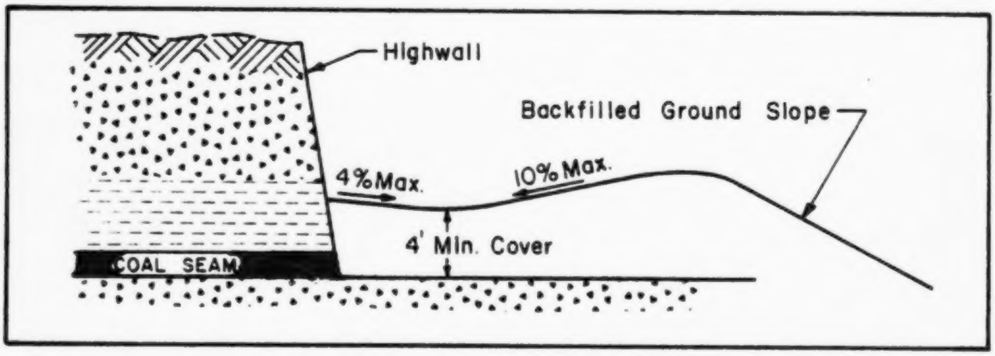

Highwall
Backfilled Ground Slope
4% Max.
10% Max.
4' Min. Cover
COAL SEAM

Figure 14-C. Typical Georgia v-ditch backfill.

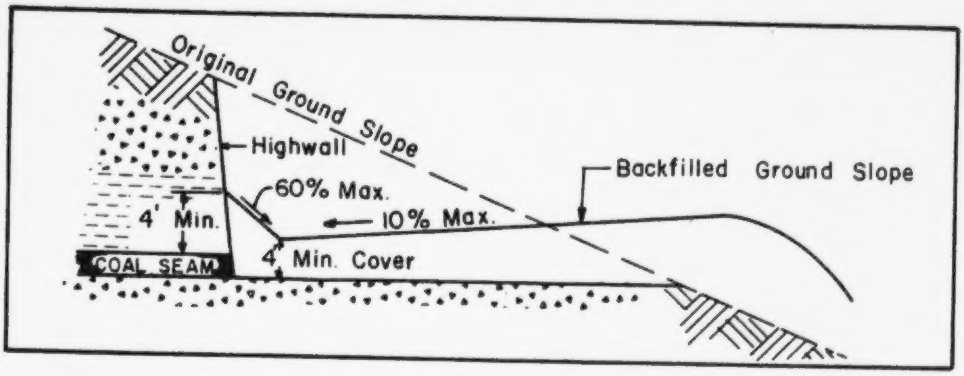

Original Ground Slope
Highwall
Backfilled Ground Slope
60% Max.
4' Min.
10% Max.
4' Min. Cover
COAL SEAM

Figure 15-A. Typical reverse terrace (I) backfill.

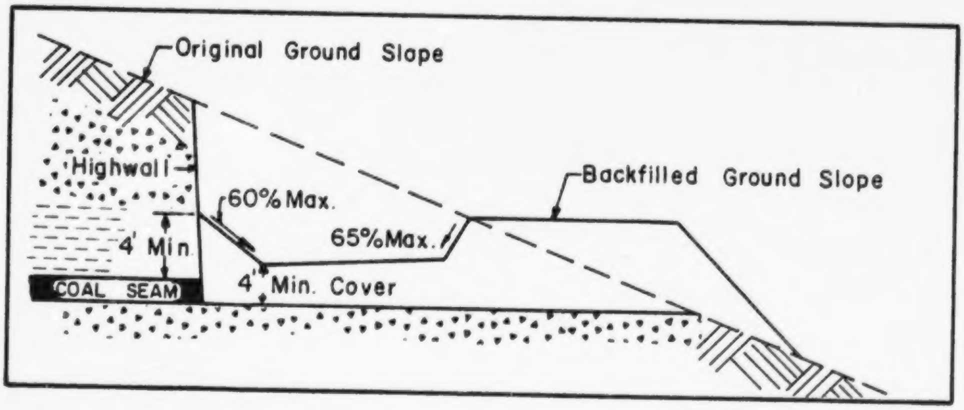

Original Ground Slope
Highwall
Backfilled Ground Slope
60% Max.
65% Max.
4' Min.
4' Min. Cover
COAL SEAM

Figure 15-B. Typical reverse terrace (II) backfill.

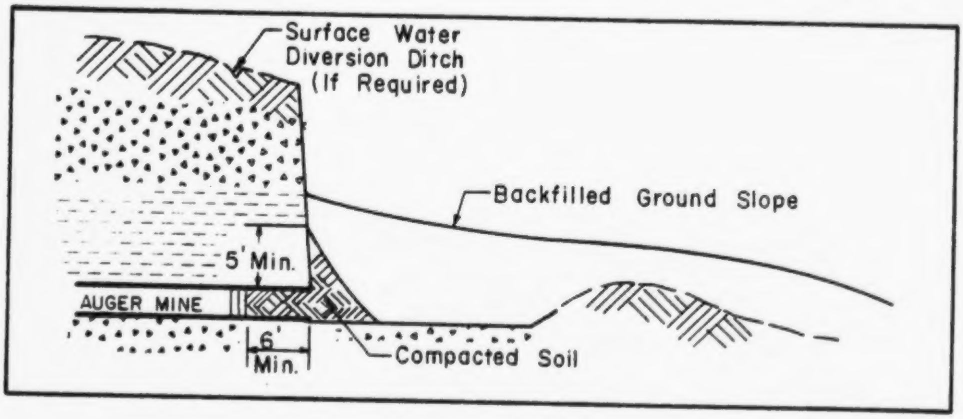

Surface Water
Diversion Ditch
(If Required)
Backfilled Ground Slope
5' Min.
AUGER MINE
6' Min.
Compacted Soil

Figure 15-C. Typical backfill - auger mine.

fracturing and decrease the rate of surface water infiltration.

Site investigations in the Dents Run watershed indicate that the majority of surface mines had intercepted underground mine workings, high-walls were generally highly fractured and surface water runoff in these areas was usually channelled directly into the underground mine workings.

Several of the surface mines contained water impoundments in portions of the unreclaimed pit areas. Reclamation work in these areas required draining of these impoundments, and employing portable treatment facilities to provide adequate treatment of all water impoundments prior to discharge to a receiving stream.

SECTION 6

SITE CHARACTERIZATIONS

SECTION B - DRIFT MINE OPENINGS 1, 13, AND 14 PRIORITY III (WAYNESBURG COAL)

Drift mine openings 1 and 13 have fallen in and are overgrown with underbrush. There is a small amount of water seepage immediately in front of these openings. The total seepage from drift mine opening 1 is less than one-half gallon per minute and the total seepage from drift mine opening 13 amounts to two to three gallons per minute. Drift mine opening 14 is still accessible. The present opening is approximately 5 feet high by 8 feet wide. There is a pond of water immediately in front of this opening which is approximately 25 feet long by 10 feet wide (refer to sample 38, Table C-36). Due to the relatively high quality of this discharge water (pH 8.0) and the present condition of these openings, additional work is not recommended for this site.

SECTION B - DRIFT MINE OPENINGS 4, 5, AND 6 PRIORITY III (WAYNESBURG COAL)

Drift mine openings 4 and 5 are approximately 5 feet high by 8 feet wide. There is a small pond of water at the mouth of each opening. These openings appear to be very shallow (approximately 10 feet deep) and have apparently been opened strictly for house coal. There is a small seepage of water immediately in front of these openings. Drift mine opening 6 is approximately 5 feet high by 10 feet wide at the mouth. This opening also has a small amount of water ponded immediately behind the mouth of the mine. It appears to have been developed to a greater extent than drift mine openings 4 and 5; however, it is impossible to tell how extensive the mine really is. There is also a small seepage of water from this drift mine opening. The total seepage from drift mine openings 4, 5, and 6 amounts to less than one gallon per minute. This seepage was sampled on September 20, 1971 (refer to sample 36, Table C-34). Due to the relatively high quality of the discharge (pH 7.6) from these openings and the inaccessiblity of both openings from any main or secondary highway, reclamation work is not recommended for this site.

SECTION B - STRIP AREA B
PRIORITY III (WAYNESBURG COAL)

The total length of this strip area is approximately 1,000 feet, the height of the highwall is approximately 20 feet, and the width of the bench is approximately 150 feet. The height of the outslope averages approximately 30 feet. This strip area has been backfilled with the slope toward the highwall. It is apparently a very old strip, as the area is now covered with a heavy growth of underbrush. This strip area is not visible from any of the major or secondary highways in the area. Surface water drainage would be toward the highwall; however, there is only a slight amount of acidic material present on the bench of this strip area and there are no drift mine or auger mine interceptions within the highwall. Therefore, the pollution problem resulting from this drainage would be minimal. Due to the present condition of this strip area, there would be no significant advantage to performing additional reclamation work.

SECTION B - STRIP AREA C
PRIORITY III (WAYNESBURG COAL)

The total length of this strip area is approximately 1,500 feet; the height of the highwall is approximately 50 feet, and the width of the bench varies from 150 to 250 feet. The outslope is approximately 50 feet high. This strip area has not been backfilled, and there is no vegetative cover on either the outslope or the bench. There is quite a bit of acidic material left on the bench and the outslope. The strip is highly visible from one of the major highways in the area (West Virginia Route 46). There are two deep mine interceptions in the northeastern portion of this strip area (mine openings 7 and 8). Recommended reclamation at the site includes compacted earth seals of the mine openings involved, regrading of the spoil banks and the outslope to near original contour, placement of a surface water diversion ditch along the upper portion of the highwall, soil conditioning of the backfill material in order to establish a firm vegetative cover and planting of the area in some species of trees or grass. It should be noted, however, that this strip is presently under active permit and any reclamation work completed at this site should be the responsibility of the permittee.

Mine openings 7 and 8 are deep mine interceptions rather than actual drift mine entries. The entrances of both interceptions are partially covered by material that has fallen from the highwall. Both openings are approximately 7 feet high by 12 to 15 feet wide. Mining in this area would have been to the dip so that surface water would run into the mine rather than drainage running out of the mine. A compacted earth seal should be installed in each of these openings to prevent surface water from entering the mine.

Drift mine opening 10 was apparently abandoned quite some time ago. The opening has fallen in and is overgrown with underbrush. There is no evidence of any water seepage at this time or at any time in the past. Reclamation work is not recommended at this opening.

Drift mine opening 11 was apparently the main opening to a small drift mine. The opening is partially covered by material which has fallen from above the mouth of the mine. The present opening is approximately 7 feet high by 15 feet wide. There is no evidence of any water seepage. Reclamation work is not recommended at this location.

Drift mine opening 12 is almost totally covered by underbrush and debris. There is no evidence of water seepage from the mine. Reclamation work is not recommended at this opening.

SECTION C - STRIP AREA B
PRIORITY III (WAYNESBURG COAL)

The total length of this strip area is approximately 2,600 feet. The height of the highwall varies from 35 to 50 feet and the width of the bench varies from 125 to 200 feet. This strip mine has not been backfilled and there is a significant amount of acidic material present on both the bench and outslope. There is no vegetation on either the bench or outslope. The height of the outslope is approximately 75 feet and the surface condition is very rough. The condition of the highwall varies between very firm in some areas to extremely fractured in other areas, which seems to indicate the presence of drift mine interceptions. There are three ponded areas in this strip mine and each pond averages approximately 50 feet wide by 200 feet long (refer to sample 20, Table C-20). Figure 16 shows a portion of one of the ponded areas in the northern section of the strip pit. There are two large shovels and two other pieces of heavy equipment present at this site. This equipment does not appear to be in operable condition and should be removed. This strip mine is highly visible from one of the secondary roads in the area and may be visible from Interstate 79. Figure 17 shows a portion of the exposed highwall of this strip site as viewed from West Virginia Route 46. There is

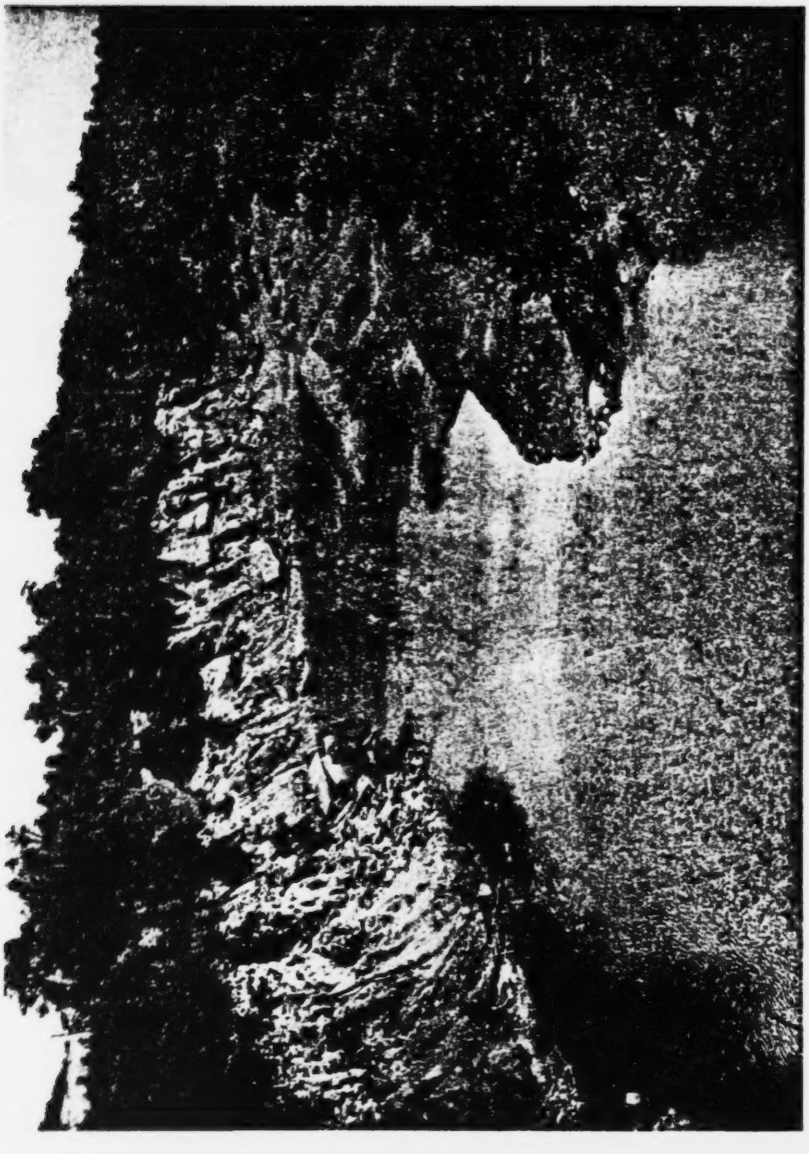


Figure 16. Section C, strip area B.

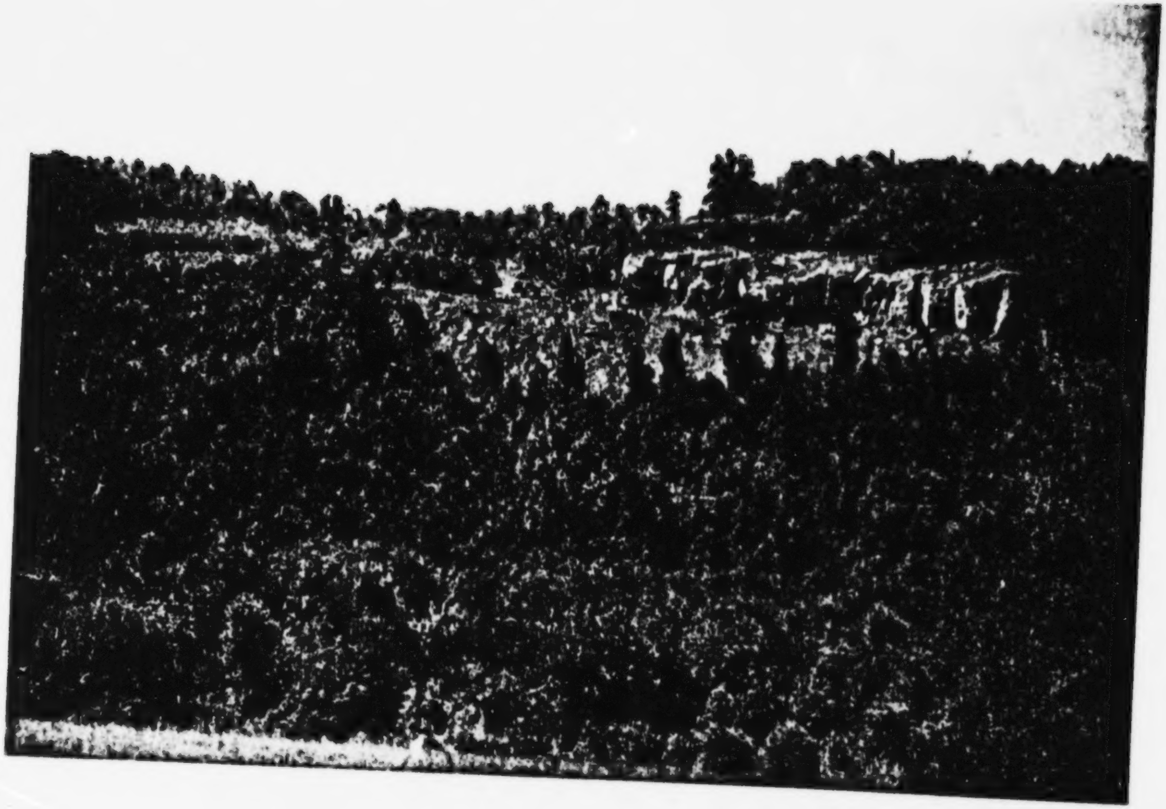


Figure 17. Exposed highwall, Section C, strip area B.

one drift mine entry in the extreme southern section of this strip (drift mine opening 2). The roof of this entry has collapsed and is overgrown with underbrush. There was no drainage from this entry at the time of inspection and no evidence of any significant drainage at any time in the past. Recommended reclamation at the site includes removal or burial of solid waste and heavy equipment, burial of acidic material present, regrading of spoil banks and outslope to contour or pasture backfill conditions, soil conditioning required to establish a firm vegetative cover and replanting of the area in some species of trees.

SECTION C - STRIP AREA C
PRIORITY I (WAYNESBURG COAL)

The total length of this strip area is approximately 2,600 feet, the width of the bench varies from 100 to 150 feet, and the height of the highwall is approximately 50 feet. The condition of the highwall is very solid, which indicates that there have been no drift mine interceptions in this area. With the exception of approximately 500 feet in the northwestern portion of this strip area, most of the strip has been backfilled with the slope toward the highwall. This area has apparently been planted in grassess which are just beginning to grow. The outslope, however, has no vegetative cover and the condition of this area is very rough. The northwestern section of this strip area has not been backfilled and the base of the highwall has apparently been extensively auger mined. Since the auger mining would have been to the dip in this area, all surface drainage eventually enters these auger mines. Figure 18 shows a portion of this area with associated surface water runoff. This entire strip area will probably be visible from Interstate 79. Reclamation work required at the site should include earth compaction seals in each of the auger mine openings to prevent surface water infiltration, regrading of the spoil bank and outslope in the northwestern portion of the strip to a contour backfill, planting of the area in some species of trees or grasses.

SECTION C - STRIP AREA D
PRIORITY III (SEWICKLEY COAL)

Strip area D has apparently been abandoned for quite some time. The area appears to have been backfilled, although this may also be the result of natural weathering and erosion. The total length of the strip is approximately 600 feet and the height of the existing highwall is 10 to 15 feet. The strip itself is now covered with a heavy growth of trees and underbrush. There is no evidence of drift mine openings or drift mine interceptions.

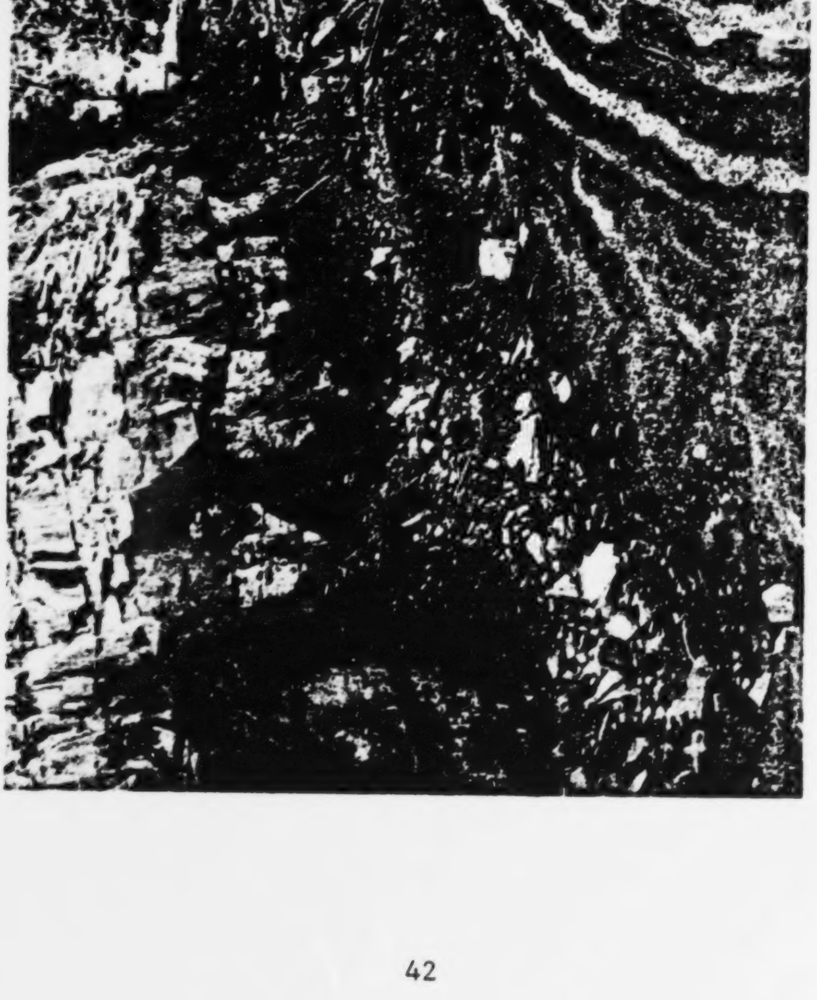


Figure 18. Highwall and bench showing surface water runoff, Section C, strip area C.

Due to the present condition of this strip area, surface water drainage would probably follow natural courses and eventually drain into stream M7-1 (refer to Figure 12). This drainage should not create any significant pollution problems. Due to the natural reclamation of this area and the relative inaccessibility from any major highway, additional reclamation work at this site is not warranted.

SECTION C - STRIP AREA E
PRIORITY III (REDSTONE COAL)

This strip area has been almost totally eliminated by the Interstate 79 road construction. The total length of the remaining strip area is approximately 200 feet, the height of the highwall is approximately 15 feet, and the width of the bench is approximately 50 feet. The area has been backfilled with the slope toward the highwall and has been planted in pine trees. There is a good growth of both underbrush and pine on the backfilled area. There are no apparent drift mine interceptions or drift mine openings into this strip area. Due to the slope of the backfill, surface water drainage would probably drain toward the highwall and eventually into stream M7-1; however, there is very little acidic material left uncovered in this area and the drainage should not be contaminated. Portions of this strip area will be visible from the new Interstate highway. From an aesthetic point of view, these areas should probably be regraded to an original contour backfill and planted in some type of trees; however, the area does not present any significant drainage problems and the money required to completely reclaim this area could probably be put to better use elsewhere.

SECTION C - STRIP AREA F
PRIORITY III (SEWICKLEY COAL)

Strip area F appears to be a continuation of strip area G. The height of the existing highwall is approximately 20 feet, the width of the bench is approximately 50 feet, and the total length of this strip area is approximately 1,500 feet. The extreme northern section of this strip area has been reclaimed by the Interstate 79 road construction. Natural weathering and erosion have reduced the height of the highwall and spoil banks in the remaining section of the strip to near original contour conditions. The area is now covered with a very dense growth of underbrush and trees. There are four apparent drift mine openings in the extreme northern section of strip area F (drift mine openings 5, 6, 7, and 8). Two of these openings have fallen in and are now covered over. The remaining two entries are still accessible. Since these openings would have been worked to the dip, any surface water drainage would drain into the subsurface water system. This drainage would probably be insignificant in quantity since this strip area is located at the crest of a hill; however, the area is easily accessible and it would be relatively inexpensive to place a clay compaction seal in each of the openings to eliminate surface water infiltration. Due to the present condition of this strip area, it is believed that further reclamation work attempted in this area would be more detrimental than beneficial; however, several areas are presently devoid of vegetative cover and should be revegetated.

SECTION C - STRIP AREA G
PRIORITY III (SEWICKLEY COAL)

The height of the highwall in this strip area is approximately 20 feet, the width of the bench is approximately 50 feet, and the total length is approximately 1,500 feet. This area was apparently worked quite some time ago, and is now overgrown with underbrush and trees. There are several areas along the base of the highwall that appear to have intercepted drift mine workings; however, they have fallen in and are partially overgrown. For the most part, these drift mine interceptions would have been into mines that had been worked to the rise in this area, and therefore any drainage would tend to be from the drift mine workings rather than into them. Drift mine opening 19 is located in the north central section of this strip area. This drift mine opening has fallen in and is now overgrown. There is no evidence of drainage either into or out of any of the drift mine openings or drift mine interceptions located in this strip area. Natural weathering and erosion have reduced the height of the highwall and spoil banks to near original contour conditions. Since the area has now stabilized and is presently covered with a heavy growth of underbrush and trees and there is no significant drainage from this strip area, it is believed that any further reclamation work attempted at this site would be more detrimental than beneficial. There are several areas that have apparently been used as refuse dumps; soil conditioning could be utilized in these areas in order to help establish a firm vegetative cover, providing there are sufficient funds in the project to permit this work.

SECTION C - STRIP AREA H
PRIORITY II (SEWICKLEY COAL)

The height of the highwall in strip area H varies from 15 to 35 feet, the width of the bench varies from 75 to 150 feet, and the total length of this strip is approximately 2,000 feet. Most of this strip area has been backfilled with the slope toward the highwall; however, the southern and western portions of the strip have not been backfilled. There is a heavy growth of black locust on the northern section of the strip which appears to be between 5 and 10 years old. There are three drift mine entries into the highwall of the central and western portions of this strip area (drift mines 11, 12, and 13). All of these entries were apparently worked to the dip and, therefore, drainage should be into the mine rather than out of the mine. Each of the three entries is open and the dimensions of each of the mine openings are approximately 5 feet high by 12 feet wide. A compacted earth seal should be adequate at each of these entries since mining was to the dip and there is no head of water expected on the seal. There is a pond of water in the western section of the strip pit which is approximately 50 feet long; the water in this pond is highly discolored, indicating the presence of high concentrations of iron. Recommended reclamation work at the site should include placement of a surface water diversion ditch at the base of the highwall in the northern section (there would be no advantage to regrading the entire area since there is a well established growth of trees in this area), installation of earth compaction seals in each of the drift mine openings, treating and draining the ponded water in the western section of the strip, contour backfilling of the remaining portion of the strip, and soil conditioning of this portion of the strip in order to establish a firm vegetative cover.

SECTION C - STRIP AREA J
PRIORITY II (SEWICKLEY COAL)

The height of the highwall in strip area J varies from 15 to 35 feet and the width of the bench averages approximately 200 feet. The condition of the highwall varies from solid in the eastern portion of the strip to highly fractured in the western portion. The eastern portion of the strip has not been backfilled and the present spoil bank is approximately 20 feet high. The western section of the strip has been backfilled, apparently to aid in the development of the drift mine into the highwall of the strip. There are three drift mine openings in this portion of the strip, drift mine openings 14, 15, and 16. These openings all appear to have been main haulage tunnels. The mouths of drift mine openings 14 and 15 are still open; however, the roof of the haulage tunnel itself appears to have collapsed a short distance behind the mouth of the mine. The roof of drift mine 16 has fallen in. Each of these openings could have been worked to either the rise or the dip and it is difficult to estimate the direction of mining without accurate mine maps; however, drift mine opening 14 was apparently worked to the rise, since there is an active discharge from this opening amounting to approximately two gallons per minute. There are several areas along the western portion of the highwall which have apparently been drift mine interceptions and are now collapsed. Due to the extremely fractured conditon of the highwall in this area, it is doubtful that any type of water seal would be effective. There is an actively burning refuse dump just north of drift mine opening 15. This dump is approximately 50 feet long by 50 feet wide by 30 feet high (see Figure 19). Recommended reclamation work required at the site includes installation of wet seals at mine openings 14 and 16 (reference Figure 20), installation of a compacted earth seal at mine opening 15, regrading the strip area to a contour backfill, extinguishing the fire in the refuse dump, burial of the material along the base of the highwall, and conditioning the backfill material so that the area may be planted in some species of grass or trees.

SECTION C - STRIP AREA K
PRIORITY III (SEWICKLEY COAL)

Strip area K appears to be quite old and there is a heavy growth of trees and underbrush along the entire length of the strip. The strip extends along the hillside and is approximately 1,200 to 1,500 feet long. Natural weathering and erosion have reduced the height of the highwall and spoil banks to near original contour conditions. There are no apparent openings into deep mine workings at this site. There would be little or no advantage to reworking this area. However, there is one old coal tipple and several junked automobiles in the area which could be removed.

SECTION C - STRIP AREA L
PRIORITY III (WAYNESBURG COAL)

This area was stripped at the crest of a hill and there is only a small portion of the highwall remaining. Other sections of the highwall have evidently been removed in order to provide material for the backfill. This strip is 700 to 800 feet long by approximately 200 feet wide. The outslope is 50 to 70 feet high. The condition of the outslope is very rough, and there is only sparse vegetative cover on the bench and outslope. Recommended reclamation at the site is limited to soil conditioning and planting of the area in some species of trees.

SECTION C - MINE DUMP P

Mine dump P is an active refuse dump and slurry pond of the Consolidation Coal Company. The slurry pond area is 1,200 to 1,500 feet long by 450 feet wide. The area surrounding this pond is presently being used as a refuse dump

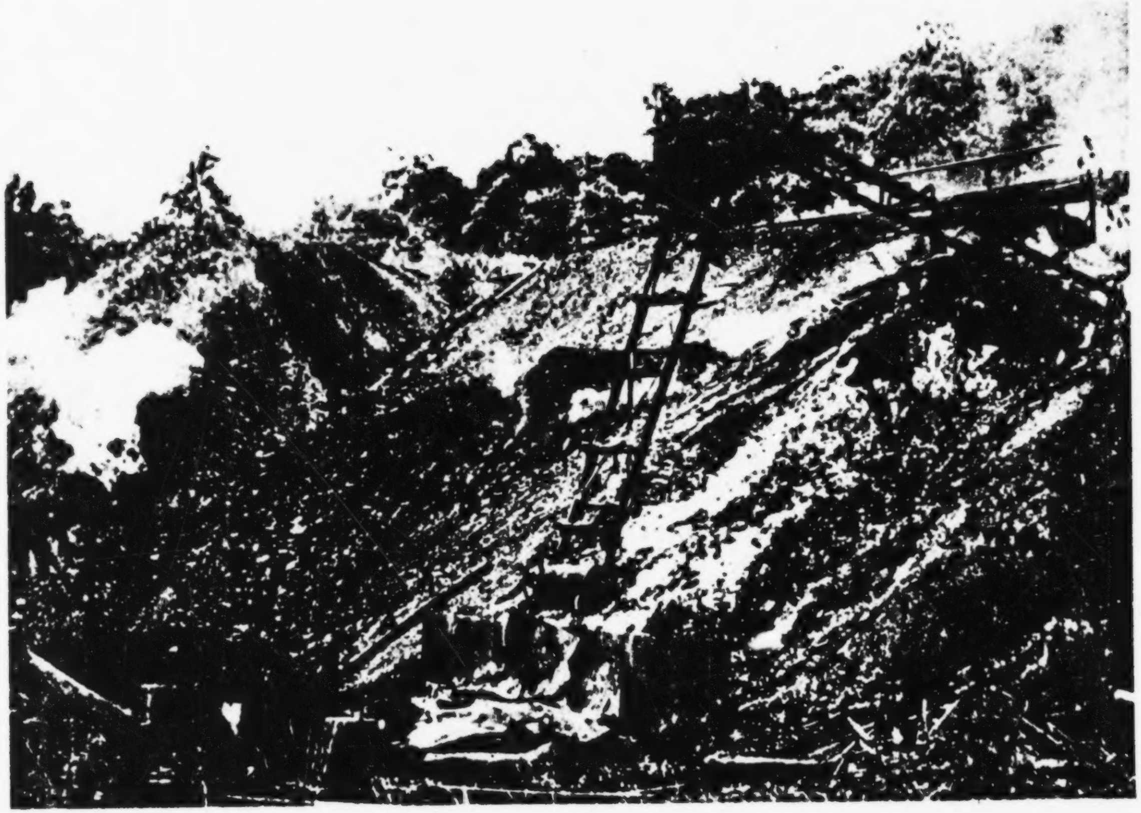
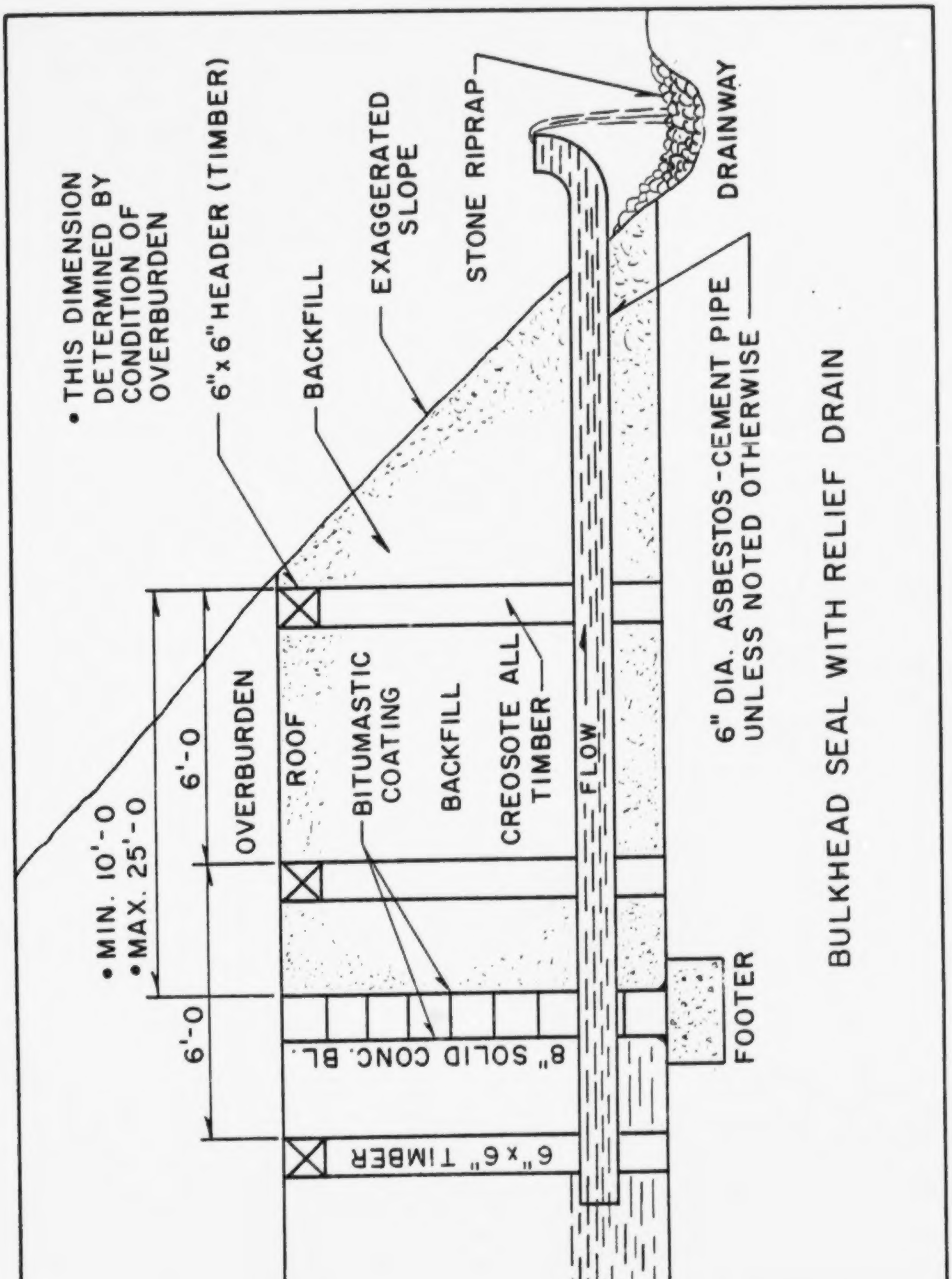


Figure 19. Burning refuse dump, Section C, strip area J.



• THIS DIMENSION DETERMINED BY CONDITION OF OVERBURDEN
6"x 6" HEADER (TIMBER)
BACKFILL
EXAGGERATED SLOPE
STONE RIPRAP
DRAINWAY
• MIN. 10'-0
• MAX. 25'-0
6'-0
6'-0
OVERBURDEN
ROOF
BITUMASTIC COATING
BACKFILL
CREOSOTE ALL TIMBER
FLOW
6" DIA. ASBESTOS-CEMENT PIPE UNLESS NOTED OTHERWISE
8" SOLID CONC. BL.
6"x 6" TIMBER
FOOTER
BULKHEAD SEAL WITH RELIEF DRAIN

Figure 20. Bulkhead seal with relief drain.

and is approximately 1,500 feet long by 300 feet wide. There is seepage from the south end of the slurry pond of approximately 20 gallons per minute during the fall of the year (refer to sample 22, Table C-22). Consolidation Coal is responsible under the West Virginia state regulations, for this area and the treatment of any discharge resulting from this operation. This problem will be solved by the completion date of the project. As of this writing, Christopher Coal Division has not submitted plans for the correction of the problem area. Several alternative control methods are being studied.

SECTION C - MINE DUMP Q

Mine dump Q is an active refuse dump of the Christopher Coal Division of the Consolidation Coal Company. This dump is approximately 1,000 feet long by 300 feet wide and 40 to 50 feet deep. There is a continuous discharge from the eastern portion of this dump which averages 25 gallons per minute during the fall of the year (refer to sample 19, Table C-19). Since this is still an active refuse dump, Christopher Coal is responsible for the elimination or treatment of this discharge under the West Virginia state regulations.

SECTION C - STRIP AREA S
PRIORITY II (REDSTONE COAL)

The height of the existing highwall in this strip area is approximately 30 feet, the width of the bench is approximately 50 feet, and the length of the strip area is approximately 1,500 feet. This area has not been backfilled; however, the site has apparently stabilized and is now covered with a relatively heavy growth of underbrush and trees. Natural weathering and erosion have reduced the height of the highwall and spoil banks to near original contour conditions. There were no drift mine interceptions or drift mine entries located in this area; however, the presence of several refuse dumps would seem to indicate that there were several drift mine openings in this area at one time (see Figure 21). These openings have apparently fallen in and are now overgrown. These refuse areas should be conditioned with fertilizers and lime in order to establish a firm vegetative cover. Due to the present condition of strip area S, it is believed that any further reclamation attempted at this site would be more detrimental than beneficial.

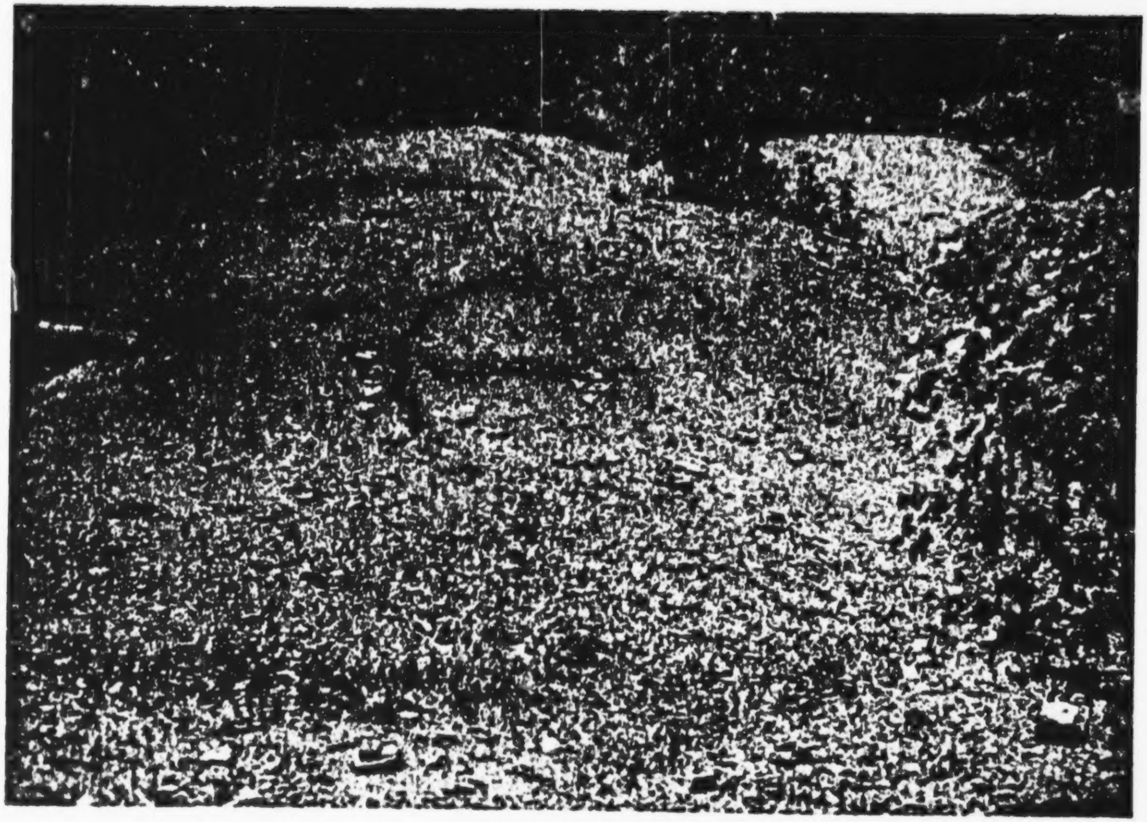


Figure 21. Abandoned refuse dump, Section C, strip area S.

SECTION C - STRIP AREA T
PRIORITY III (WAYNESBURG COAL)

The length of this strip is approximately 700 feet, the height of the highwall is generally between 35 and 40 feet, and the width of the bench varies from 50 to 200 feet. This is apparently an old strip cut judging from the dense cover of trees and underbrush on the bench and the eroded condition of the highwall. There are several openings into drift mine workings located along the highwall (drift mine openings 17 and 18). These appear to be interceptions rather than actual drift mine entries. Since the drift mine would have been worked to the dip in this area, surface drainage would flow into the mine rather than out of the mine. This possibly could be eliminated by placing compacted earth seals at each of the openings and placing surface water diversion ditches along the base of the highwall. The outslope to this strip is overgrown with trees and underbrush, and there would be little advantage to regrading this area.

SECTION C - STRIP AREA U
PRIORITY III (WAYNESBURG COAL)

The total length of this strip area is approximately 150 feet and the height of the highwall is 25 to 30 feet. The southeastern portion of this strip area was apparently worked quite some time ago, since the area is now eroded and overgrown with underbrush. However, the northeastern portion of this area (approximately 60 feet) is still apparently being used by local residents for house coal supplies. There are no drift mine entries or drift mine interceptions in this area. There is no visible drainage from the area at this time; however, surface water drainage from this area would most likely drain into stream M7-1 (refer to Figure 12). The spoil banks and uncovered acidic material in this area are insignificant due to the relatively small size of the area. Additional reclamation is not recommended at this site.

SECTION C - DRIFT MINE OPENINGS 9 AND 10
PRIORITY III (SEWICKLEY COAL)

Drift mine opening 10 was apparently a main haulage tunnel of a small drift mine. This mine was evidently worked to the rise and, therefore, any drainage within the mine would probably be drained from the mine at this point. The mine has apparently been abandoned for quite some time; the roof of the opening has collapsed and is overgrown with underbrush and some small trees. There was no drainage from this entry at the time of inspection, or evidence of any significant drainage at any time in the past. Reclamation is not recommended for this site.

Drift mine opening 9 was apparently the ventilation course for the same small drift mine. The mine is still accessible through the ventilation fan opening at this entry. There is a small pond of water immediately in front of the opening; however, this appears to be surface water drainage rather than drainage from the mine itself. There does not appear to have been any significant drainage from this entry at any time in the past. Reclamation is not recommended for this site.

SECTION F - STRIP AREA A
PRIORITY II (WAYNESBURG COAL)

The length of this strip is approximately 1,800 feet; the width of the bench is 100 to 125 feet. The height of the highwall averages approximately 30 feet, and the outslope is approximately 50 feet high. The highwall is relatively solid, and there are very few fractured areas. There are no visible openings into drift mines. The strip is located at the crest of a hill, and the overburden between the coal seam and the surface area is 30 to 40 feet. The area has not been backfilled, and there are spoil banks over the entire width of the bench. There is some volunteer growth on the area which appears to be about five years old. This vegetative cover is confined to a very small area of the strip, and the growth in these areas is sparse. The entire area (the bench, the highwall, and the outslope) contains considerable acidic material, and there is evidence of drainage and erosion on the outslope. There were no indications of drainage from the area at the time of inspection. At present, there are two abandoned shovels and one tractor trailer on the strip (see Figure 22). These should be removed, as it is doubtful that they can be moved under their own power. Recommended reclamation at the site includes removal of all solid wastes, contour backfilling of the entire strip area, soil conditioning of the backfill, and planting of the area in some species of trees or grasses.

SECTION F - STRIP AREA B
PRIORITY III (WAYNESBURG COAL)

The height of the highwall is 20 to 25 feet, the width of the bench varies from 100 to 300 feet, and the outslope is 15 to 20 feet high. The total length of the strip mine is approximately 600 feet. This strip is located about one-tenth of a mile south of U.S. Route 19, but it is not highly visible from the road due to the vegetative growth in the area. The condition of the highwall is relatively stable, which indicates the absence of drift mine entries or interceptions. The area has been backfilled with the slope toward the highwall (Figure 23). There are areas where

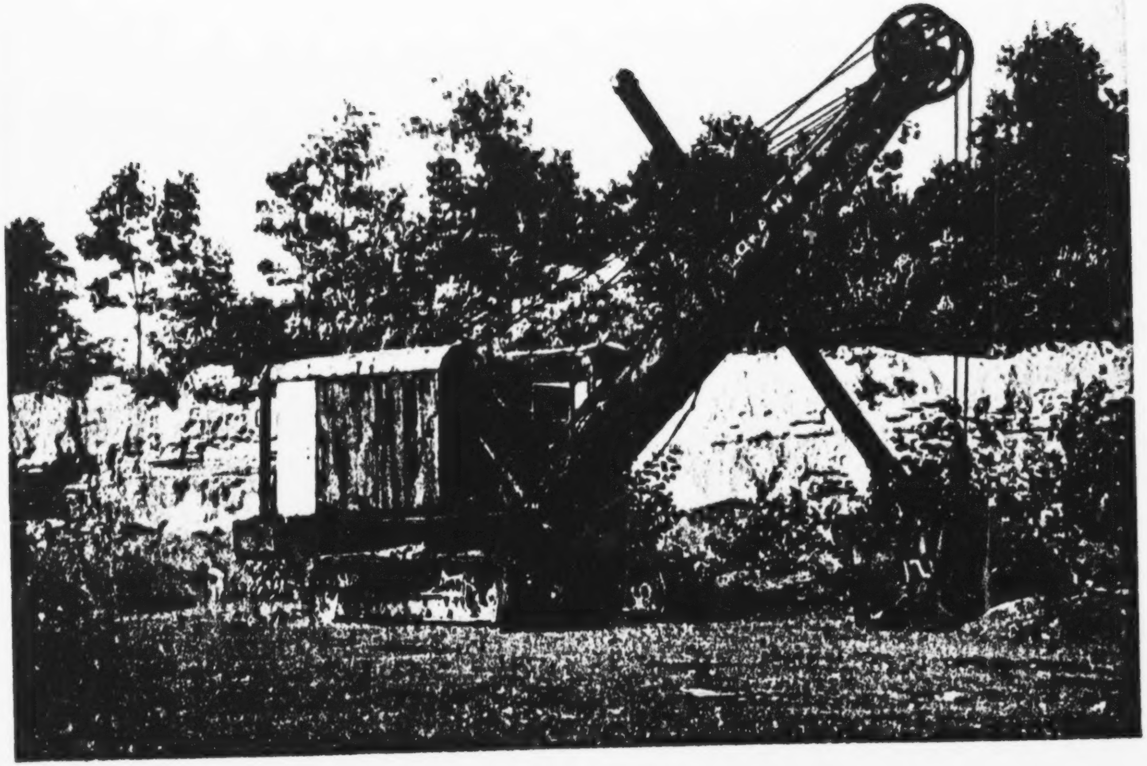


Figure 22. Abandoned coal equipment, Section F, strip area A.

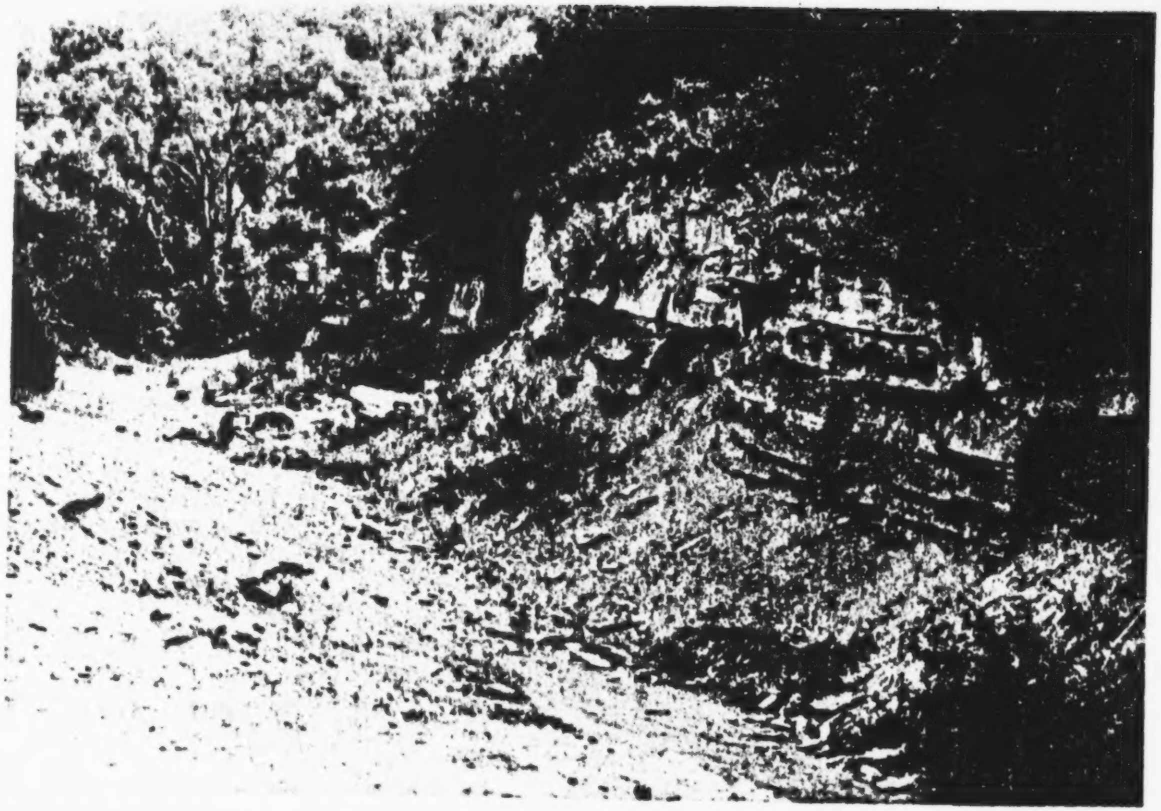


Figure 23. Typical reverse terrace backfill, Section F, strip area B.

there have been visible runoffs toward the highwall, but there was no apparent seepage from the area. There is a growth of black locusts on the backfill which appears to be several years old and the area has also been planted in pines which are presently one to two feet high. Recommended reclamation at the site includes soil conditioning and supplemental planting of the area in some species of trees or grasses.

SECTION F - STRIP AREA C
PRIORITY III (WAYNESBURG COAL)

There are apparently two benches at this strip site. The height of the highwall varies from 25 to 75 feet, the width of the bench is approximately 300 feet, and the total length of this strip is approximately 3,000 feet. This strip has been backfilled with a contour backfill, and the backfilled area has recently been planted in grasses. The highwall appears very solid, indicating the absence of drift mine entries or interceptions. There appears to be some acidic material on the backfill, but it does not appear to be affecting the growth of the grasses. This is an exceptionally good backfill; however, from a purely aesthetic point of view, the highwall should be lowered. The outslope of the strip mine is approximately 75 feet high. Portions of this strip area have been planted in grasses and the remainder has apparently been prepared for planting. Recommended reclamation at the site includes regrading the outslope, soil conditioning, and seeding of unplanted areas in some species of trees.

SECTION F - DRIFT MINE OPENINGS 1, 2, 3, AND 4
PRIORITY III (WAYNESBURG COAL)

Drift mine opening 1 has apparently fallen in and is now sealed. It is one opening of a group of four. This drift mine appears to have been abandoned quite some time ago, as indicated by the appearance of the entries and the mine tracks in the area. Drift mine opening 2 is still accessible and is approximately 10 feet wide by 7 feet high. There is a small amount of seepage from this entry, totaling approximately one-half gallon per minute. The water was sampled in August 1971 (refer to sample 30, Table C-30). The pH at that time was 6.8, alkalinity exceeded acidity, and total iron was 2.2 ppm. Drift mine opening 3 has partially fallen in. Part of the coal seam is still exposed. There is water ponded in the entry; however, there does not appear to be any seepage from the opening. Drift mine opening 4 is apparently part of the same small drift mine. The entry has fallen in and is now overgrown. There is no apparent seepage from the entry and no signs of seepage at any time in the past. There is a small spoil bank approximately 20 feet wide by 20 feet long and 5 feet high which is not visible from the road.

The mines are located just north of an infrequently traveled dirt road. There are only meager signs that the mines ever existed in this area (a small refuse dump exists alongside the road). Due to the relatively high quality of the water discharged from these mines and their inaccessibility, reclamation is not recommended at this site.

SECTION G - STRIP AREA A
PRIORITY I (WAYNESBURG COAL)

The exposed highwall of strip area A averages 30 feet, the width of the bench is approximately 125 feet, and the height of the outslope is approximately 40 feet. The total length of this strip is approximately 1,500 feet. The condition of the highwall is generally very solid. There is one section near the southeast portion of the strip which is highly fractured; the fracture zone runs at a 45 degree angle to the highwall and extends back approximately 50 feet. There is also some local subsidence in the area. The fracture zone and subsidence area would require some type of grout or clay compaction seal in order to reduce surface water infiltration. The strip area has been backfilled and the bench dips slightly toward the highwall; however, there is no vegetative cover on either the bench or the outslope. There are several areas along the highwall in which there are exposed auger holes. Only four auger holes are now open in the area since the strip has been backfilled; however, it is probable that augering has been completed along the entire length of the strip. The surface drainage courses in this area direct all surface water into the auger openings. Recommended reclamation at the site includes sealing of the fractured area, placement of a surface water diversion ditch above this area, compaction sealing of the auger areas, regrading of the bench and outslope to pasture backfill, soil conditioning and establishment of a good vegetative cover in the area.

SECTION G - STRIP AREA B
PRIORITY II (SEWICKLEY COAL)

Strip area B is located approximately 75 feet below and parallel to strip area A. Strip area B was evidently worked quite some time ago, judging by the appearance of the spoil banks and the vegetative cover in the area. The area has been backfilled; however, natural weathering and erosion have reduced the height of the highwall and spoil banks to near original contour conditions. The width of the bench of this strip varies from 50 to 450 feet, and the total length is approximately 2,000 feet. There appears to be a considerable amount of acidic material exposed on the spoil banks and outslope; however, any attempts to regrade or otherwise disturb this area would probably be more detrimental than advantageous. Recommended reclamation at the site includes conditoning of the spoil banks, and supplemental planting of some species of trees.

SECTION G - STRIP AREA C
PRIORITY II (SEWICKLEY COAL)

The height of the existing highwall in strip area C is 20 to 25 feet, the width of the bench varies from 50 to 300 feet, and the height of the outslope is 20 to 30 feet. The total length of the strip is approximately 1,500 feet. The area has been backfilled with a slight dip of the backfill toward the highwall. The condition of the outslope is fairly smooth; however, there is no vegetative cover on the outslope or the bench (see Figure 24). There are no visible drift mine openings or interceptions in the area. There is evidence of surface runoff and, judging from the iron stains on the bottom of the stream bed, the drainage is acidic in nature. The location of the strip represents the headwaters of stream M7-3. The total drainage from all of the surface runoff from any of the strip mines in the area is eventually drained into M7-3. This stream has been sampled on several occasions (refer to sample 24, Table C-24). Recommended reclamation at this site includes soil conditioning (neutralization and fertilization) and planting of some species of trees or grasses.

SECTION G - STRIP AREA D
PRIORITY II (WAYNESBURG COAL)

The highwall in strip area D varies from 20 to 50 feet, the width of the bench is approximately 75 feet, and the outslope is 20 to 25 feet high. The extreme southeastern section, the portion in which drift mine opening 31 is located, has recently been backfilled and planted in grasses. The existing highwall in this section is approximately 40 feet high. This is generally a very good backfill; however, nothing has been done to the outslope, and the slope of the backfill itself is slightly toward the highwall. The remaining section of strip area D, from drift mine opening 30 to the extreme northern section of this strip, has not been backfilled. The height of the spoil banks in this section varies from 25 to 45 feet. There is considerable acidic material along the bench and on the spoil banks of the strip, and very little vegetative cover exists over most of the area.

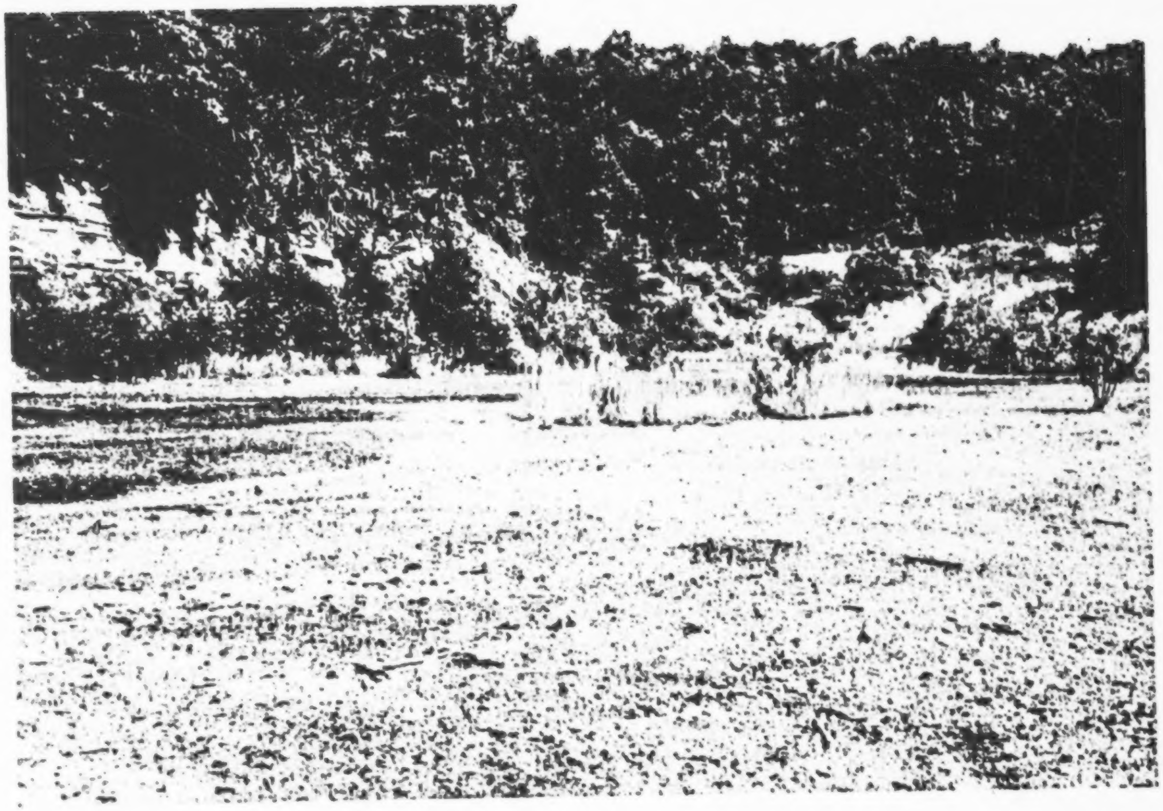


Figure 24. Regraded bench area showing lack of vegetation, Section G, strip area C.

Drift mine opening 29 was apparently the main haulage tunnel for what appears to have been a large drift mine. The original opening has partially fallen in, and the existing opening is approximately 4 feet high by 15 feet wide. This opening, as well as all other openings which are found in this strip area, has been mined to the rise so that any drainage would be from the mine rather than into the mine. At present, there is no drainage from this particular opening; however, there is evidence immediately in front of the opening that there has been drainage at times. The drainage course is highly stained, indicating the presence of high concentrations of iron. Drift mine opening 30 was apparently an alternate haulage route. The dimensions of this opening are similar to those of drift mine opening 29. There are no signs of drainage from the opening either now or in the past. Drift mine opening 28 was apparently a ventilation tunnel. The present opening is approximately 4 feet in diameter. Up to this point, there is no sign of drainage from the mine entry. Drift mine opening 27 appears to have been a drift mine interception into one of the main haulage tunnels. The present opening is quite large, approximately 5 feet high by 20 to 25 feet wide. There is a large pond of water immediately behind the material which has fallen from the highwall in front of this opening. There are also signs of seepage immediately in front of the opening. Drift mine openings 25 and 26 are very similar in appearance to drift mine opening 27. However, they have partially fallen in and it is not known whether water is ponded behind each of these falls. Drift mine openings 23 and 24 are also drift mine interceptions; however, they have fallen in and are now covered over. There is evidence along the base of the highwall of the strip area that water has drained from each of the openings at one time or another; however, the drainage appears to have been small in quantity. As reclamation work is completed at strip area A, Section G, infiltration into the deep mine workings could be decreased with a consequent reduction in the drainage from strip area D.

Recommended reclamation at the site includes installation of a wet seal at mine opening 29, installation of compacted earth seals at the remaining mine openings, complete pasture backfilling, conditioning of the backfill in order to permit the establishment of a firm vegetative growth, and planting of the area in some species of grasses or trees.

SECTION G - STRIP AREA E
PRIORITY III (SEWICKLEY COAL)

Strip area E is located below and parallel to strip area D. The strip was evidently worked quite some time ago and is now overgrown with a heavy stand of trees and underbrush. The strip mine was not backfilled and there are several areas which still contain excessive amounts of acidic material. However, any disturbance to these areas would probably be more detrimental than beneficial. Natural weathering and erosion have reduced the height of the highwalls and spoil banks to near original contour conditions. There is evidence of two drift mine openings in the southern portion of this strip (drift mine openings 60 and 61). These entries have caved in and are overgrown; however, there is a small amount of seepage in front of each of the entries. The seepage amounts to less than one-half gallon per minute. Due to the present condition of this strip area, the only reclamation recommended at this site would be soil conditioning and revegetation of those areas which are presently devoid of vegetative cover.

SECTION G - STRIP AREA F
PRIORITY III (WAYNESBURG COAL)

The highwall in strip area F is 35 to 40 feet high, the width of the bench is approximately 125 feet, and the height of the outslope is 35 to 40 feet. The total length of this strip is approximately 600 feet. The highwall is relatively solid, which indicates the absence of drift mine interceptions. Most of the area has been backfilled with the slope toward the highwall; approximately 30 yards in the extreme northern section of this strip has not been backfilled. There are some grasses and light underbrush growing on the backfilled area, along with several small trees. The strip is highly visible from U.S. Route 19. Recommended reclamation at the site includes soil conditioning of the bench and outslope and planting of the area in some species of trees.

SECTION G - STRIP AREA G
PRIORITY II (SEWICKLEY COAL)

The total length of the strip area is approximately 1,200 feet, the height of the highwall varies from 30 to 45 feet, and the width of the bench averages about 50 feet. The highwall is highly fractured, and there are numerous drift mine interceptions along the entire length of the strip cut. The area has not been backfilled and there is considerable acidic material on both the bench and spoil banks. There is very little vegetative cover on either the bench or the outslope. The strip area is not visible from any major or secondary highway in the area. There are approximately 10 drift mine entries or drift mine interceptions into the drift mine workings located along the highwall of the strip area.

Drift mine opening 13 is located at the extreme northern end of strip area G. The opening has fallen in and there are several areas of stagnant ponded water in front of the opening. Minimal drainage from this area combines with the drainage from drift mine opening 14. There is also an extensive area of subsidence between drift mine openings 13 and 14.

Drift opening 14 appears to be a drift mine interception rather than an actual drift mine entry. The present opening is approximately 6 feet high by 12 feet wide. Some water is ponded behind the material which has fallen from the highwall immediately in front of the opening, which has resulted in a small amount of drainage seeping through the material. The drainage amounts to five to seven gallons per minute, which combines with other drainage from the highwall of the strip area and finally discharges into stream M7-4 at the rate of seven to eight gallons per minute.

Drift mine opening 15 was also apparently a ventilation shaft. The present opening is approximately 6 feet high by 17 feet wide. There is some drainage from the opening, which combines with the drainage from drift mine opening 16 and flows into stream M7-4 at the rate of five to seven gallons per minute.

Drift mine opening 16 was apparently a main haulage tunnel. The present opening is approximately 6 feet high by 12 feet wide. There is an extensive subsidence area above the opening. At the present time, there is a drainage from the mine opening amounting to approximately three gallons per minute.

Drift mine opening 17 was apparently a ventilation tunnel. The opening has fallen in and there is drainage of two to three gallons per minute from the site.

Drift mine opening 18 was apparently a main haulage tunnel. The present opening is approximately 5 feet high by 12 feet wide (Figure 25). There is drainage from the entry amounting to five to seven gallons per minute. The drainage combines with surface water drainage from the southern half of the strip area and drains into stream M7-4 at a current rate of 30 to 35 gallons per minute.

Drift mine opening 19 appears to have been a drift mine interception at the junction of two haulage tunnels. The present opening is approximately 5 feet high by 12 feet wide. There was no sign of drainage from this entry at the time of inspection. There is a very large subsidence immediately over the mine opening.

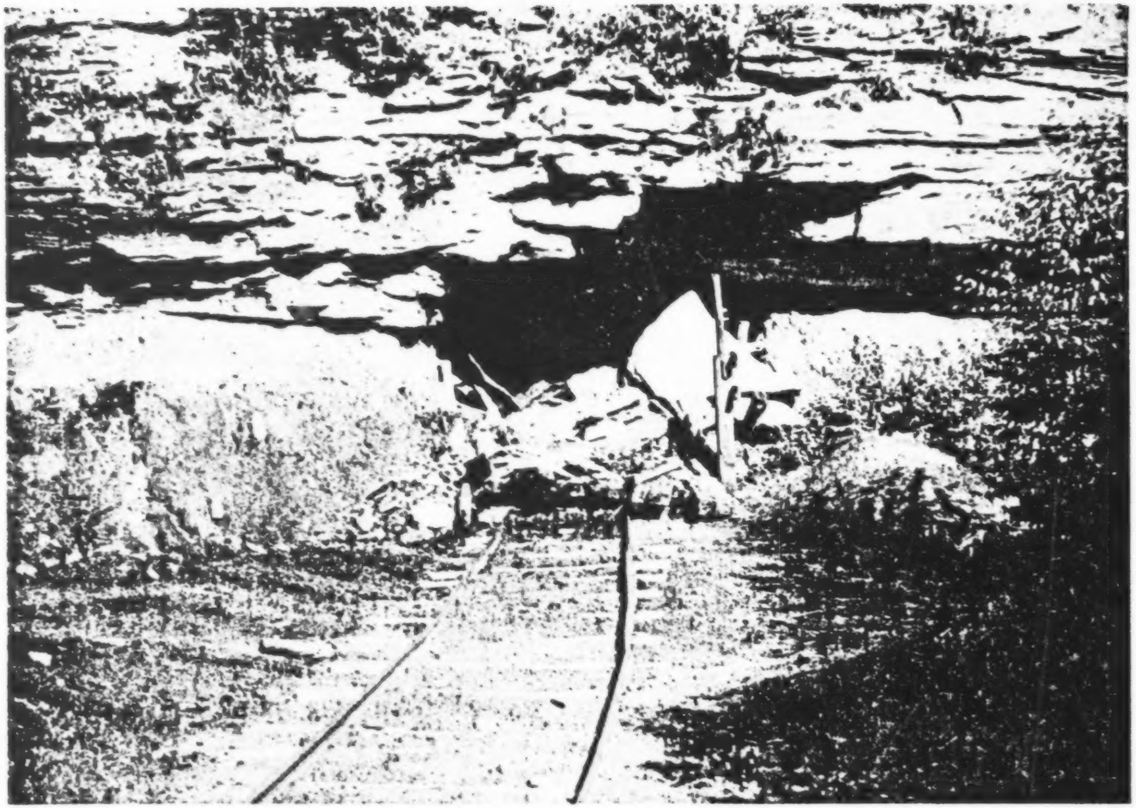


Figure 25. Typical drift mine entry, Section G, strip area G, mine opening 18.

Drift mine opening 20 was apparently used as a secondary haulage tunnel. The opening is partially covered by material which has fallen from the highwall of the strip cut. The present opening is approximately 4 feet high by 10 feet wide. There is no evidence of water behind the partial seal and no supporting evidence of drainage at any time in the past from the opening.

Drift mine opening 21 is approximately 25 feet north of drift mine opening 22. It was also apparently a main haulage tunnel. The present opening is approximately 4 feet high by 12 feet wide. The mouth of the opening is partially covered by material that has fallen from the highwall. There is no water behind the seal and no evidence of drainage from the entry.

Drift mine opening 22 was apparently one of the main haulage tunnels for the drift mine. The present opening is approximately 4 feet high by 6 feet wide. There is no apparent drainage from the drift mine opening at this time and no evidence of any significant drainage in the past.

There are also several other areas that apparently have intercepted drift mine workings; however, they have fallen in and are not accessible from the highwall. Drift mine workings along the highwall were apparently worked to the rise; therefore, any drainage would flow out of the mine rather than into the mine. At the present time, there is drainage from six of the drift mine entries; however, it appears to be surface water runoff from the highwall. Recommended reclamation at the site includes burial of all acidic material present, sealing of mine openings 16 and 18 with a wet seal, sealing each of the remaining drift mine entries or interceptions with a compacted earth seal, complete pasture backfilling of the strip area, sealing of subsidence areas, placement of a surface water diversion ditch along the upper portion of the highwall, soil conditioning of the backfill material in order to establish a firm vegetative cover, and replanting of the area in some species of trees and grasses.

The drainages mentioned above represent a period following several days of moderately heavy rainfall. The normal discharge from the mine openings amounts to five to seven gallons per minute. Due to the extensively fractured condition of the highwall and the strip area, it is doubtful that any type of a hydraulic seal would prevent future drainage from this area. In view of this condition, the money required to install hydraulic seals could not be justified. It should also be noted that the majority of the drainage from the area apparently comes from surface water runoff from the highwall rather than from the mine itself. The installation of a surface water diversion ditch along the upper portion of the highwall would reduce the volume of this drainage to insignificant levels.

SECTION G - STRIP AREA H
PRIORITY III (SEWICKLEY COAL)

The height of the highwall in this strip is approximately 40 feet, the width of the bench is 50 to 75 feet, and the spoil banks are approximately 25 feet high. The total length of the strip area is approximately 600 feet. The strip has not been backfilled; however, there is a moderate cover of trees on both the spoil bank and the bench. The trees appear to be at least 15 years old.

There are three drift mine openings in this strip cut, all of which are open. These mines were worked to the rise; however, there was no drainage from any of the openings at the time of inspection. There are signs that there has been drainage from both drift mine openings 11 and 12. This probably would have occurred during months of relatively high water. The present dimensions of each of these openings are approximately 6 feet high by 12 feet wide. Recommended reclamation at the site includes sealing of the three drift mine entries involved with a compacted earthen seal, contour backfilling, soil conditioning of the backfill, and planting of the area in some species of trees and grasses.

SECTION G - STRIP AREA J
PRIORITY I (SEWICKLEY COAL)

This area is presently being used as a sanitary landfill for the towns of Westover and Granville (see Figure 26). The sanitary landfill operator has stated that the expected life of the strip area as a landfill operation is between four and five years; however, recent public opposition to this site for future landfill usage has resulted in an injunction against the operator and it is doubtful that the area will be reopened.

The total length of the strip area J is approximately 1,000 feet. The width of the bench varies from 75 to 200 feet. The height of the exposed highwall area varies from approximately 20 feet in the areas which have already been landfilled to approximately 45 feet in areas which have not yet been landfilled.

There are approximately nine drift mine interceptions in the northern section along the highwall of the strip mine area. Since mining would have been to the dip in the area,

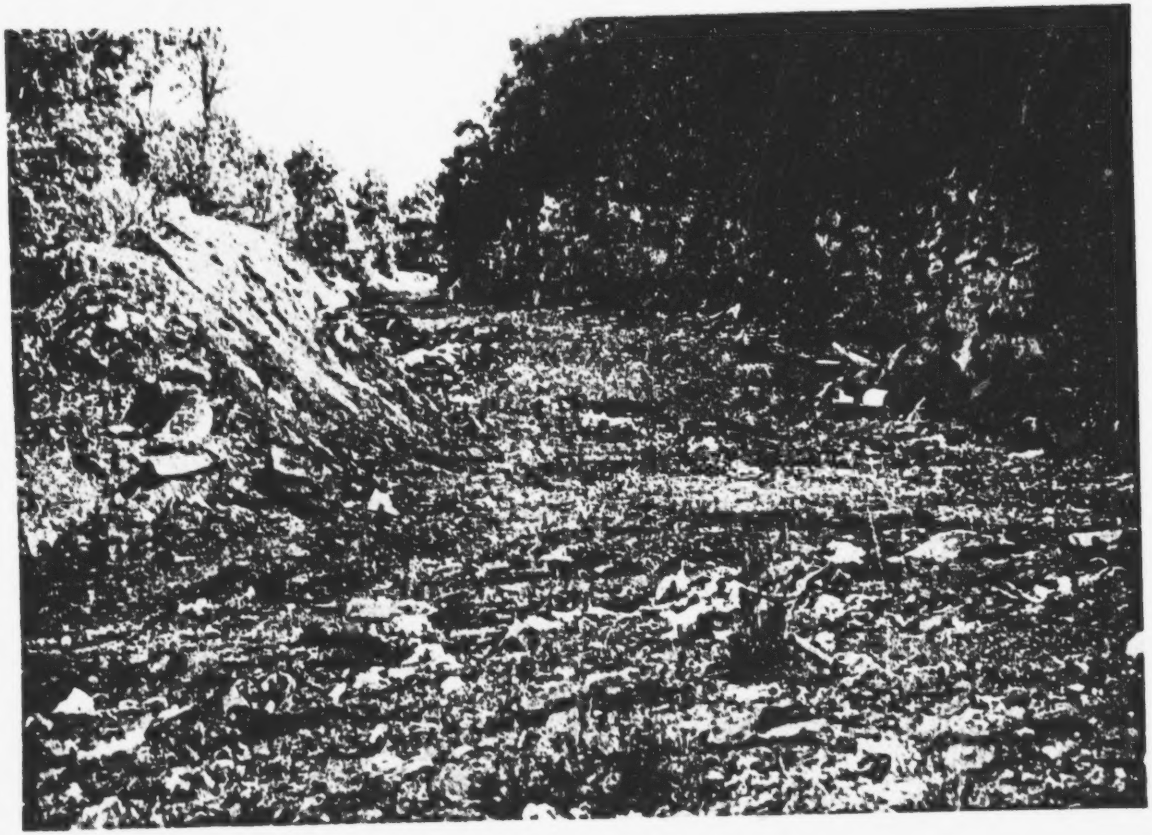


Figure 26. Sanitary landfill, Section G, strip area J.

it is suspected that any surface water falling on the strip cut or landfill operation would eventually drain into the drift mine interceptions. Several areas of extensive surface subsidence and fracturing have been located at the top of the highwall. These areas intercept a relatively large drainage area and would effectively drain any surface water into the abandoned deep mine workings.

Recommended reclamation at the site includes placement of a surface water diversion ditch along the top of the highwall, grouting or sealing of the fracture and subsidence areas near the top of the highwall, compacted contour/pasture backfill, and planting of the area in trees and grasses.

SECTION G - STRIP AREA K
PRIORITY III (SEWICKLEY COAL)

Strip area K has also been used as a sanitary landfill. The landfill has been completed and the area is now being used as a junkyard. The remaining exposed highwall area is 10 to 15 feet high. The highwall is highly fractured, and there are numerous drift mine interceptions still exposed in the area. Drift mining in the area would have been to the rise and, therefore, any drainage associated with the mining operation would drain from the mines rather than into the mines. There are no signs of drainage from any of the interceptions in this area. However, since the area has been used as a sanitary landfill operation, it is suspected that any drainage would percolate through the landfill and would not be appreciably noticeable in the area of the highwall. The outer perimeter of the landfill operation was checked for drainage. There was no visible drainage at the time and no signs of excessive drainage at any time in the past. The cover over the old landfill operation is minimal and should be increased to at least six inches in order to prevent surface water infiltration. While the area is a definite eyesore, it is not noticeable from any of the major highways in the area, despite the fact that it is immediately adjacent to U.S. Route 19. Since this area is not of major concern from a pollution viewpoint, reclamation is not recommended at this site.

SECTION G - STRIP AREA L
PRIORITY III (SEWICKLEY COAL)

The height of the highwall in this strip varies from 20 to 40 feet, the width of the bench is approximately 30 feet, and the total length of this entire section is only 600 feet. The highwall is highly fractured, which is apparently the result of numerous drift mine interceptions in the eastern section. There is some vegetative cover in this area; however, the majority of the bench and the outslope is still barren. The strip mine is located immediately adjacent to U.S. Route 19, and it is generally visible from the highway. There are several drift mine openings on the strip and immediately adjacent to the strip which could be sealed. Each opening will be discussed on an individual basis.

Drift mine openings 32 and 33 have apparently been abandoned for some time and are now fallen in and overgrown. There is no visible seepage from either of the areas; therefore, reclamation work is not required at either of the entries.

Drift mine opening 34 was apparently a main entry into this small drift mine. The opening is approximately 6 feet high by 15 feet wide. There is no evidence of drainage either into or out of the mine opening.

Drift mine opening 35 was apparently a main haulage tunnel. The mine was worked to the rise so that drainage would flow from the mine rather than into it. There were no signs of drainage from the mine, either now or in the past.

Mine opening 36 is apparently a deep mine interception rather than a drift mine opening. The opening has caved in and is now completely closed.

Mine opening 37 also appears to be a deep mine interception rather than an actual drift mine entry. The roof of this opening has collapsed. There appear to be three or four additional interceptions in this area; however, the highwall is so fractured and fallen that it is difficult to tell whether they are actual interceptions or merely areas where the fractured highwall has fallen in. The only reclamation recommended at this site would be the placement of a surface water diversion ditch along the top of the highwall in order to divert surface runoff away from the fractured highwall of this strip.

SECTION G - STRIP AREA M
PRIORITY II (SEWICKLEY COAL)

The height of the highwall is approximately 20 feet, the width of the bench is 100 to 125 feet, and the height of the outslope is 20 to 25 feet. The highwall is highly fractured, indicating the presence of deep mine interceptions or entries. The total length of the strip is approximately 600 feet. The eastern half of the strip area has been backfilled; however, a relatively poor job has been done and the area should be regraded. The western section has not been backfilled. There is some growth on the eastern section of the strip, primarily pine. The western section is devoid of vegetative cover. Some material has fallen at the base of the highwall, concealing openings into the drift mines which may be located in the area. There is one opening in the central section of the strip (drift mine opening 38). There is no discharge from this opening during the dry season; however, during the winter and spring seasons there is an almost continuous discharge which has been measured as high as 400 to 500 gpm. There are several areas that appear to have cut into the drift mine; however, they are now hidden by the material that has fallen from the highwall (drift mine opening 39). The strip is highly visible from U.S. Route 19. Recommended reclamation at the site includes installation of a wet seal at mine opening 38 and a compacted earth seal at mine opening 39, regrading of the bench and outslope to a more natural contour, soil conditioning of the backfill, and planting of trees and grasses.

SECTION G - MINE DUMP N
PRIORITY II

This refuse dump is approximately 400 feet long, 60 feet high, and varies from 50 to 100 feet wide. This area is visible from U.S. Route 19. The dump and the area below are completely devoid of vegetative cover and there is evidence of pollution from seepage water of the dump. At several points, the toe of the pile encroaches on the stream channel. Recommended reclamation at this site includes removal of all refuse in or near the stream (10 foot minimum), reshaping of the dump to a more natural contour, rerouting of surface water drainways, treatment of the refuse with fly ash and fertilizers, and planting the area with grasses.

SECTION G - STRIP AREA P
PRIORITY II (SEWICKLEY COAL)

Strip area P is located immediately below and parallel to strip area Q. Much of the area has been covered by the outslope from strip area Q. In the areas where strip area P has not been covered by the strip area Q outslope, the highwall is 20 to 25 feet high. The exposed highwall appears to be very solid and is evidently not extensively undermined. The area does not appear to have been backfilled; however, it is apparently a very old strip and is presently overgrown with trees and underbrush. While this area is generally visible from U.S. Route 19, the vegetative cover hides most of the strip mine scars. The most readily apparent scar in the area is the outslope from strip area Q. There are several points of seepage from strip area P. The total seepage from this area at the time of inspection amounted to approximately five gallons per minute. Recommended reclamation at the site should include regrading of the outslope of strip area Q to cover most of the exposed sections of the strip area. Little advantage would be gained by regrading the bench of the strip, which is presently under very heavy vegetative cover.

SECTION G - STRIP AREA Q
PRIORITY II (WAYNESBURG COAL)

The height of the highwall in this strip is 40 to 50 feet, the width of the bench is approximately 125 feet, and the outslope is approximately 75 feet high. The condition of the outslope is very rough as is illustrated in Figure 27. The length of this strip is approximately one mile. There are 20 to 25 junked automobiles on the southeastern section of the strip, along with a small amount of other solid wastes. There are eight drift mine openings on the extreme western section of the strip, two of which have active discharges (refer to sample 18, Table C-18, and sample 33, Table C-32). The entire strip is highly visible from U.S. Route 19. Portions of the highwall are highly fractured, presumably caused by the interception of drift mines (Figure 28). The strip has been backfilled with the slope of the backfill toward the highwall; however, there are only small areas where vegetative cover exists on either the bench or the outslope.

Mine opening 48 appears to be a drift mine interception rather than an actual drift mine entry. The opening is approximately 4-1/2 feet high by 12 feet wide. There are no signs of water entering or leaving this opening.

Drift mine openings 49 and 50 show no sign of water flow into or out of these mine openigns. Mine opening 50 was apparently a ventilation shaft. The opening is approximately 4-1/2 feet high by 6 feet wide.

Drift mine openings 49, 50, and 51 appear to be a part of a small drift mine which is separate from drift mine openings 52, 53, 54, and 55. The mine was developed to the dip and, therefore, any water flow would be into the mine. Drift mine opening 51 was apparently a main haulage route of this small drift mine. This opening is approximately 10 feet high by 9 feet wide. The overburden immediately above the entry is highly fractured.

Drift mine opening 52 appears to have been a main haulage route, probably for the same mine as openings 53, 54, and 55. There is a large pond of water immediately in front of the opening, which apparently originates within the mine. The pond has an active drainage of two to three

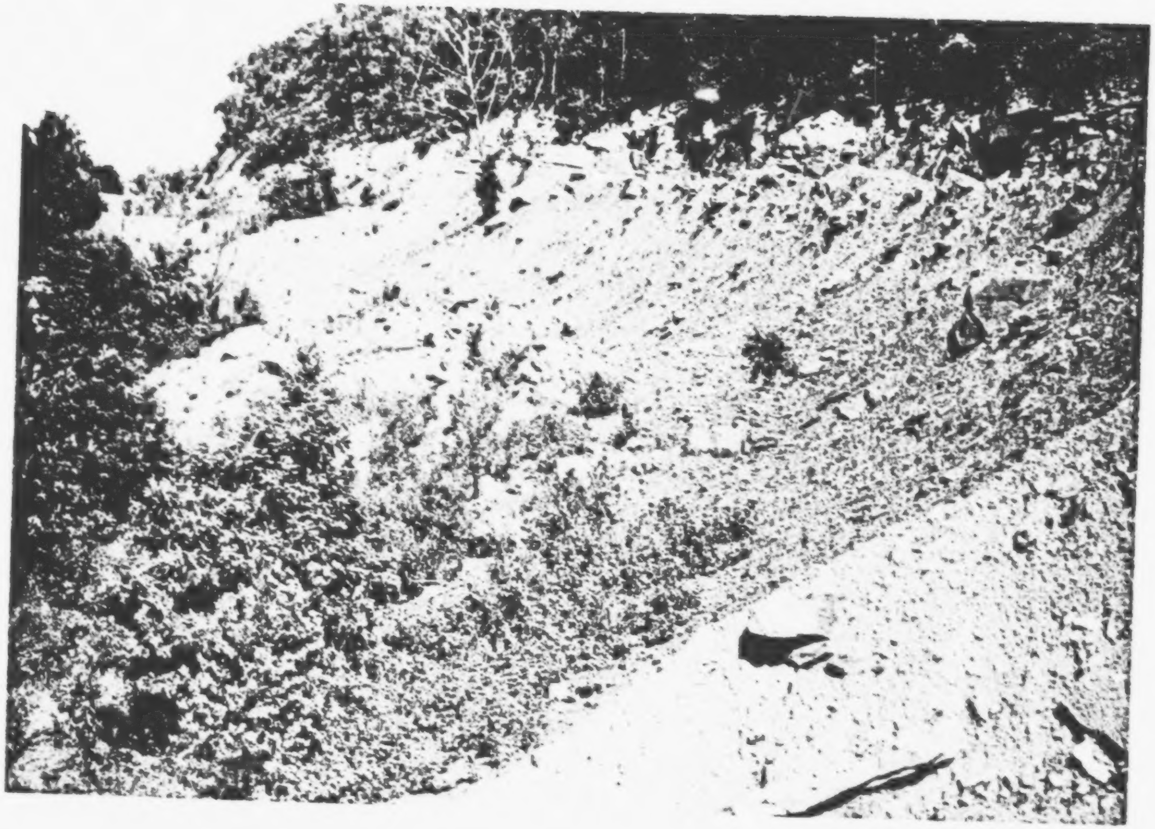


Figure 27. Typical condition of "regraded" outslope, Section G, strip area Q.

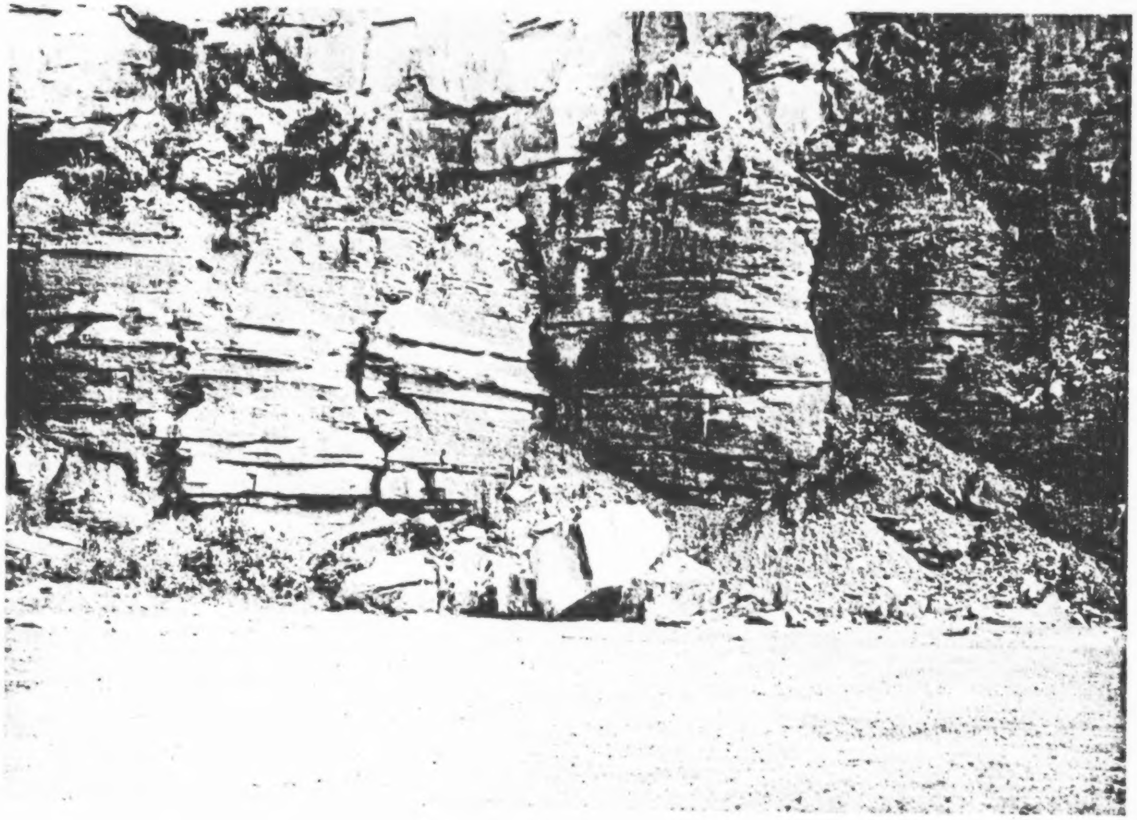


Figure 28. Fractured highwall, Section G, strip area Q.

gallons per minute. The discharge was sampled on August 31, 1971 (refer to sample 33, Table C-32).

Mine opening 53 was apparently a main haulage route. It has partially fallen in and the present opening is approximately 12 feet wide by 4 feet high (Figure 29). There is drainage from this opening amounting to approximately two gallons per minute (refer to sample 18, Table C-18).

Mine opening 54 was apparently an alternate haulage route. It is now partially sealed with a concrete block seal; however, there is an opening through the seal approximately three feet in diameter. There is a small amount of water ponded behind the seal, which presently seeps through and joins the drainage from mine openings 55 and 53.

Mine opening 55 was a ventilation shaft into what appears to have been an extensive drift mine. The opening is approximately four feet in diameter, and there is a small amount of water ponded in the opening. Material has fallen from the highwall, partially covering the opening. There is seepage through the material from the drift mine amounting to approximately one-half gallon per minute at the time of this investigation.

Reclamation at the site should include installation of wet seals at mine openings 52 and 53, installation of compacted earth seals at all remaining mine openings, regrading to a pasture backfill, removal of tipple, tracks, junk vehicles, and trash, soil conditioning of the spoil, and planting the area in trees and grasses.

SECTION G - STRIP AREA R
PRIORITY I (WAYNESBURG COAL)

This strip area can be divided into two sections, an east and a west section. Each section is described separately.

East Section

The highwall in the east section is 40 to 50 feet high, the width of the bench is approximately 250 feet and the outslope is 40 to 50 feet high. The strip mine has not been backfilled, and there is no vegetative cover on either the bench or the outslope in this area (Figure 30). There is considerable solid waste in the area which could probably be buried in the highwall when the strip area is backfilled. The highwall is highly fractured in certain areas due to extensive auger mining. There are 20 visible auger openings (Figure 31). It is estimated that there may be as many as 60 additional openings; however, material has fallen from

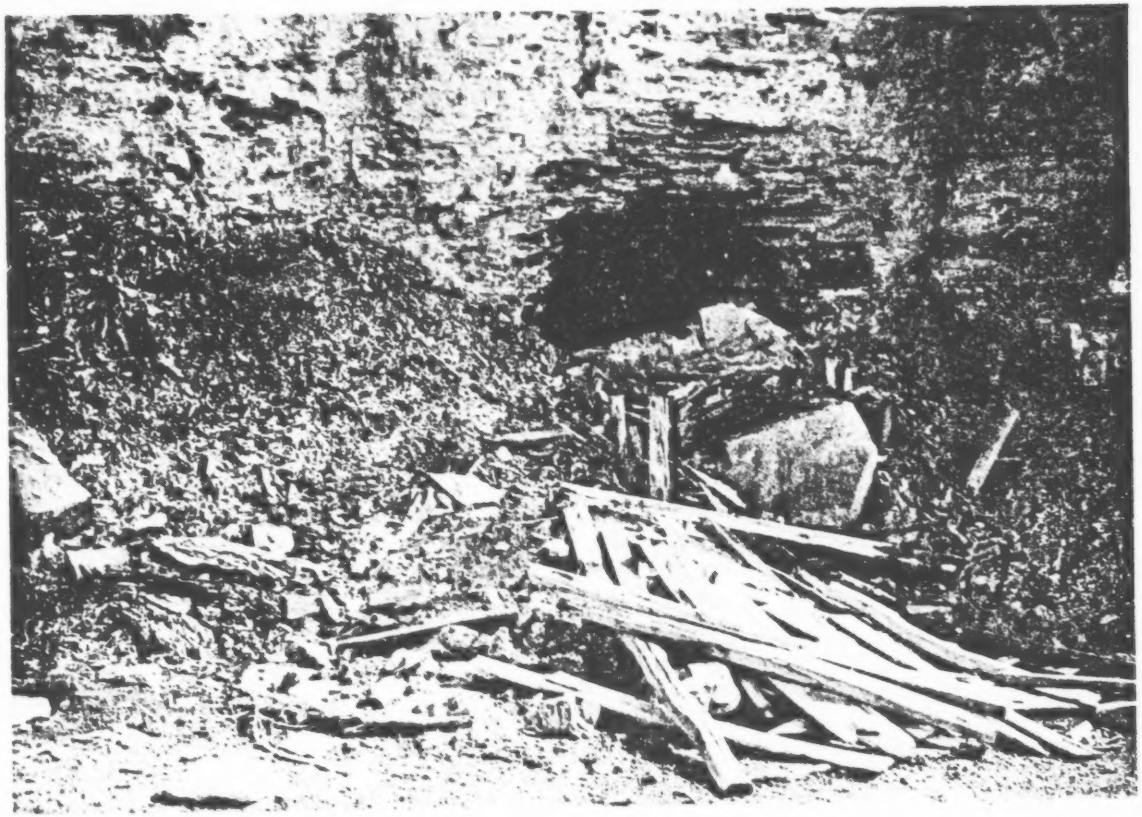


Figure 29. Typical drift mine entry, Section G, strip area Q, mine opening 53.

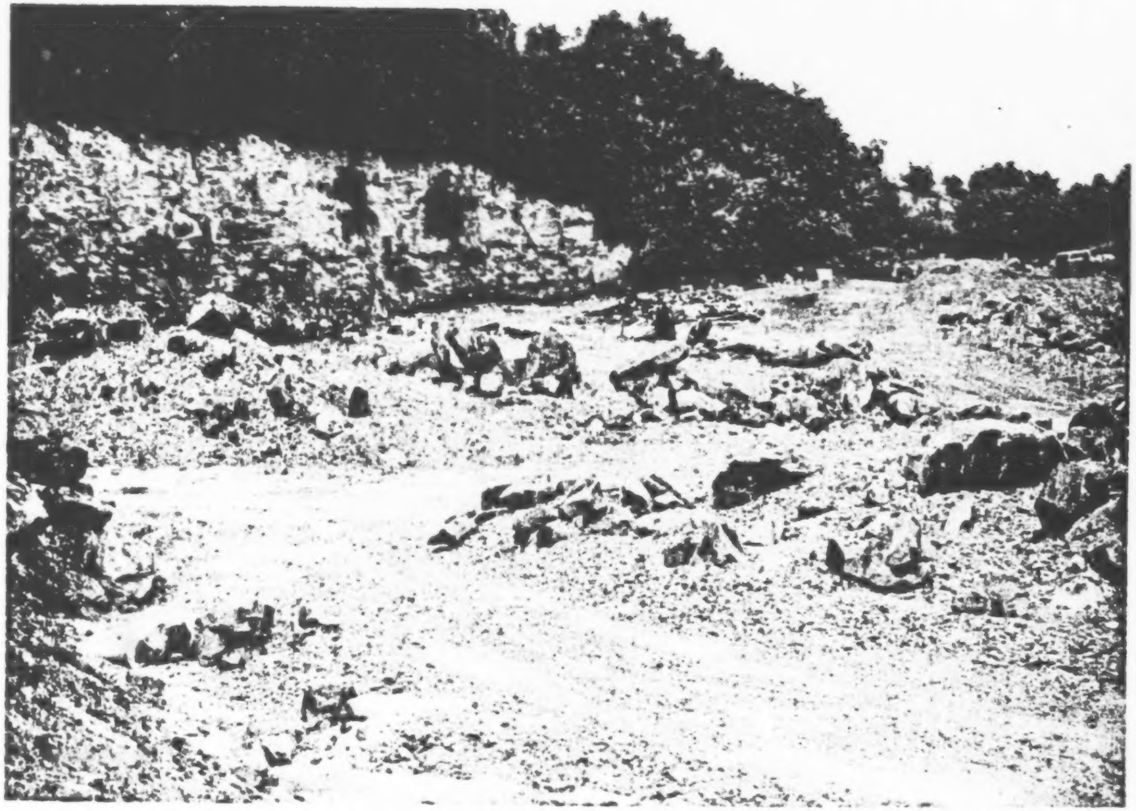


Figure 30. Typical condition of bench and highwall, Section G, strip area R.

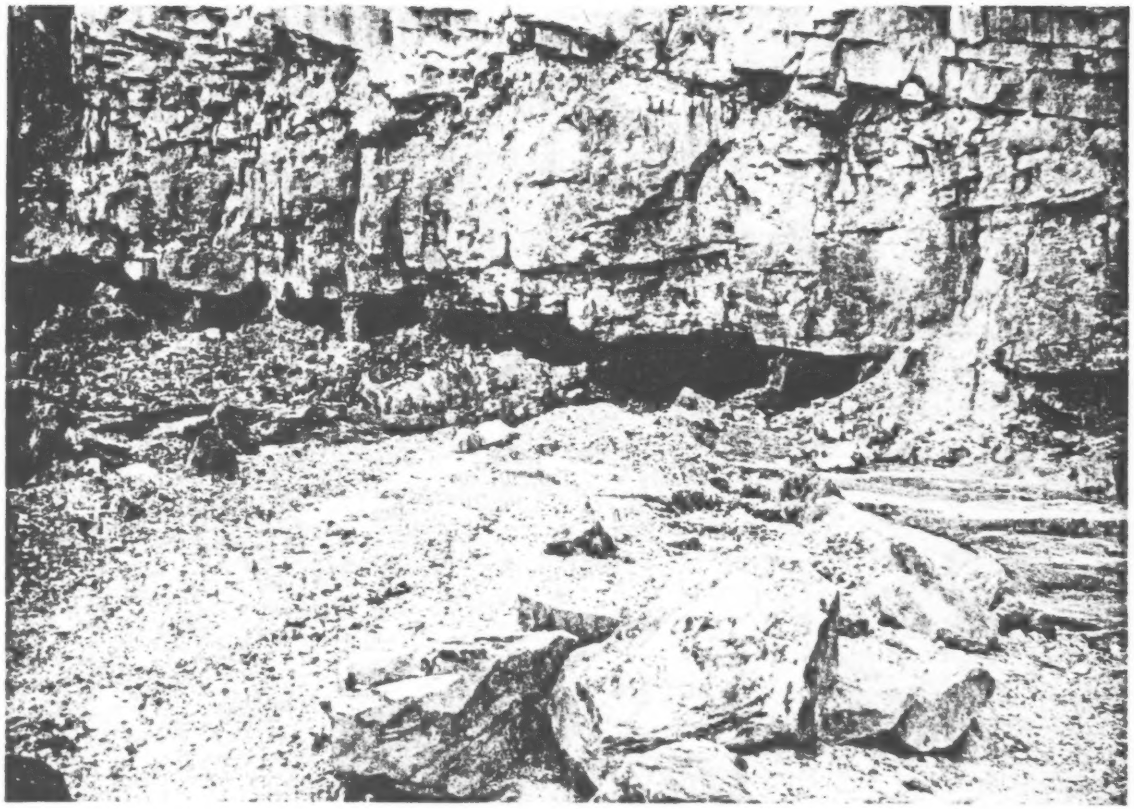


Figure 31. Typical auger openings, Section G, strip area R.

the highwall and partially covered most of these, making it impossible to determine the extent of auger mining in the area. There is evidence of water infiltration into the auger openings; however, no active drainage was observed at the time of this investigation.

West Section

The height of the highwall in the west section is 40 to 50 feet, the width of the bench varies from 50 feet to 300 feet, and the outslope is approximately 40 feet high. The highwall is highly fractured since the area has been almost totally undermined by augering (Figures 32 and 33). Many of the auger openings have cut into drift mine workings; therefore, the highwall is only supported by a small pillar of coal in several areas. There is no evidence of drainage either into or out of the auger openings; however, there is a ponded area at the extreme northwestern section of the strip approximately 40 feet wide by 125 feet long. The water in the pond is highly discolored, indicating the presence of high concentrations of iron. The water was sampled on October 21, 1971 (refer to sample 39, Table C-37).

The total length of both strip sections is approximately 1,500 feet. Reclamation work at this strip should include compaction sealing of the auger openings, contour backfilling (compacted), soil conditioning and seeding to establish a firm vegetative cover.

SECTION G - STRIP AREA W
PRIORITY III (WAYNESBURG COAL)

The height of the highwall in strip area W is 20 to 25 feet, the width of the bench varies from 75 to 200 feet, and the height of the outslope is 15 to 20 feet. Most of the area has been backfilled with what appears to be a contour backfill.

Both the bench and outslope are presently covered with a heavy growth of trees and underbrush. The trees appear to be 15 to 20 years old and consist predominantly of pine. Natural weathering and erosion have reduced the height of the spoil banks and highwall to near original contour conditions.

There are three drift mine openings in the strip area. Drift mine openings 57 and 59 have either been covered or fallen in and do not require further sealing. Drift mine opening 58 has apparently been opened strictly for house coal. This opening is approximately four feet in diameter

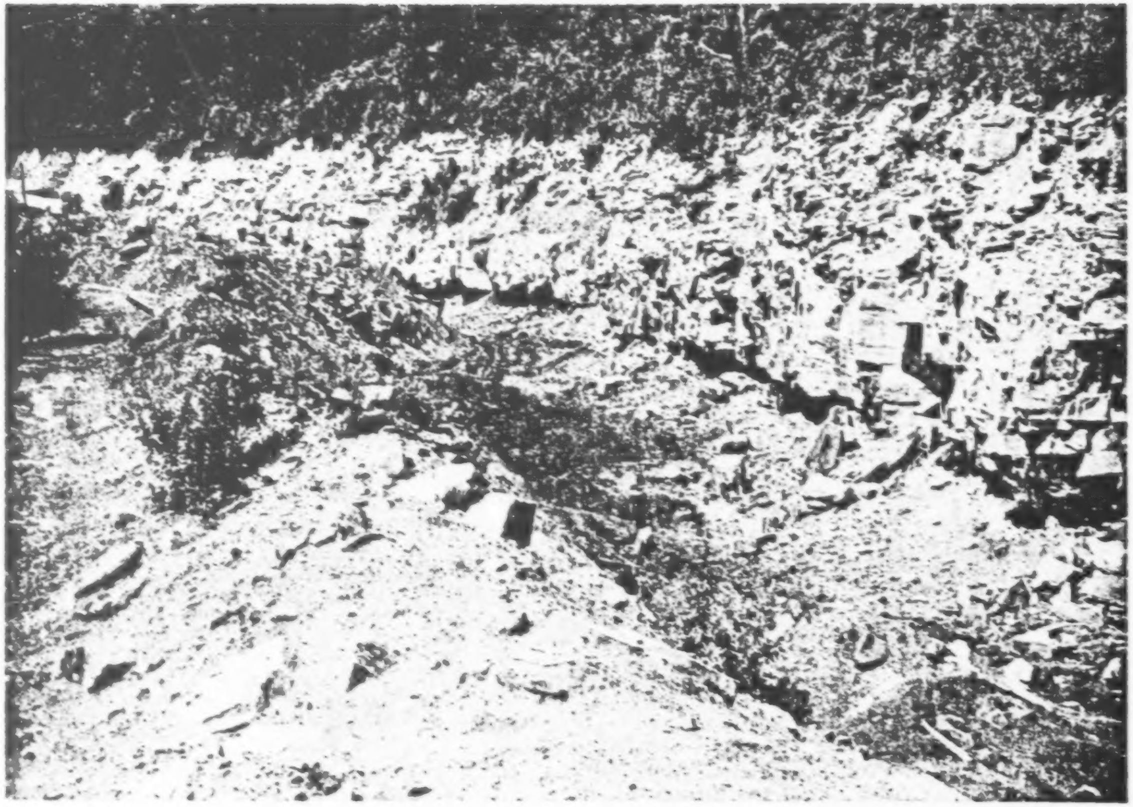


Figure 32. Fractured highwall resulting from extensive augering, Section G, strip area R.

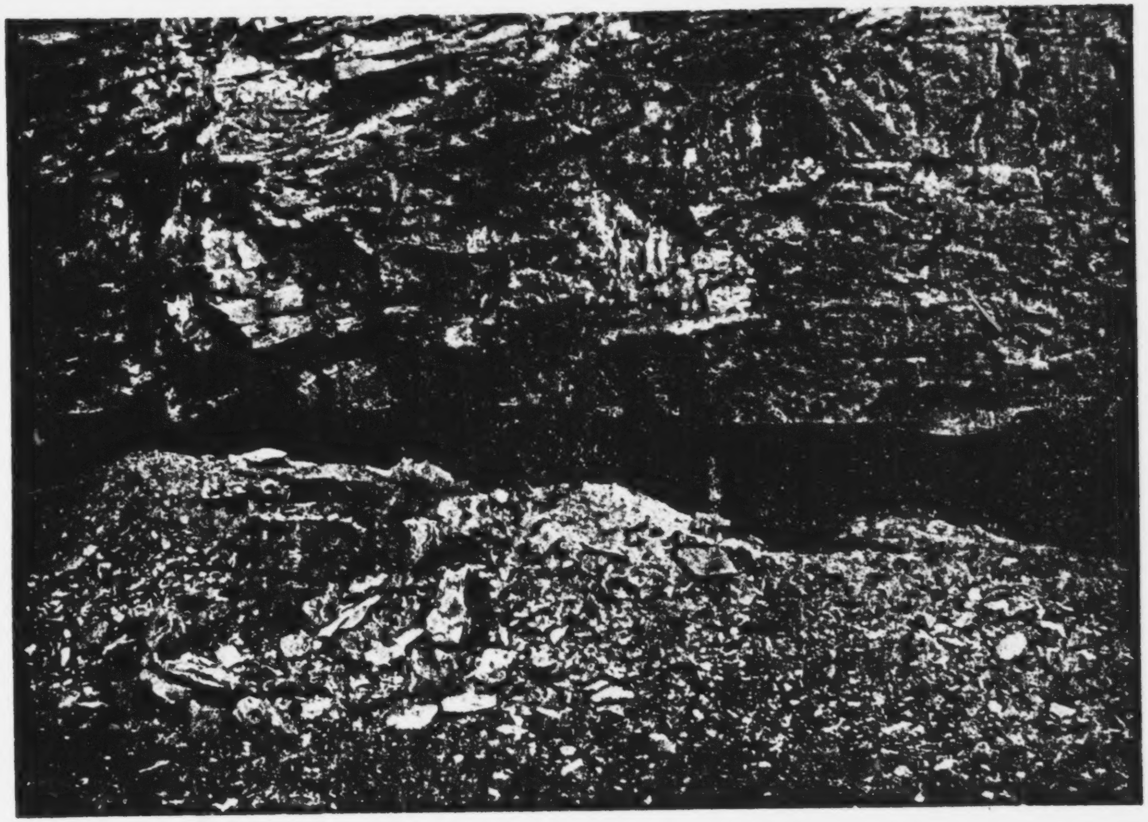


Figure 33. Augered area illustrating extent of highwall undermining, Section G, strip area R.

and the dimensions of the one small room that exists at this opening are approximately 15 feet wide by 20 feet long. There is no evidence of drainage from any of these openings.

There are two "hot spots" immediately below the area. Each of the two areas is approximately 50 feet wide by 200 feet long. The first area, immediately below drift mine opening 58, contains approximately 100 dead trees (Figure 34). The second area, below mine opening 57, is completely devoid of vegetative cover. Reclamation recommended at this strip site includes collecting soil samples from each of the "hot spot" areas and addition of whatever material may be required to establish a vegetative cover in the areas. Additional reclamation is not recommended at this site.

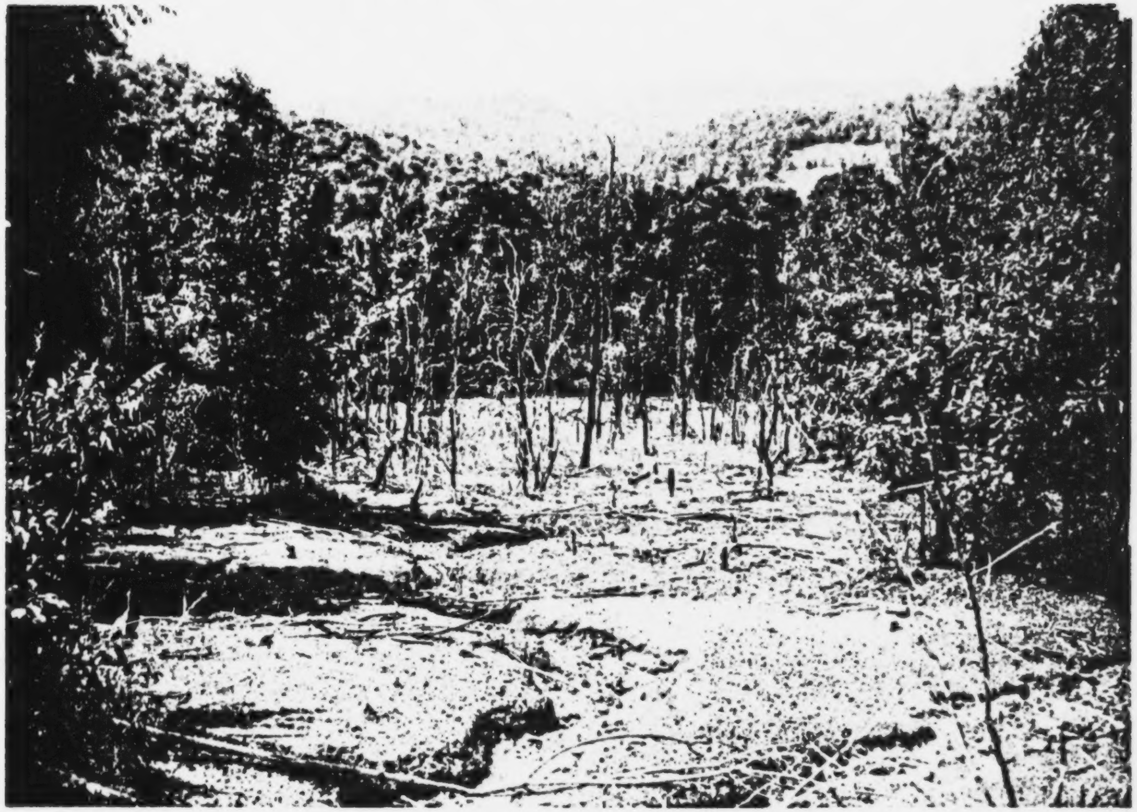


Figure 34. "Hot spot" area, Section G, strip area W.

SECTION 7

PROGRAM SURVEILLANCE AND IMPLEMENTATION

An important part of a demonstration project of this nature is documentation of the effectiveness of the control measures being employed. In this project, the objective was to monitor the quality and quantity of natural stream flows and borehole discharges in the watershed. It was felt that this approach would show both the reduction of acid mine drainage as evidenced by Consolidation Coal's reduced pumping rates, and the increase in stream quality due to the increase in natural surface water runoff.

To this end, a network of seven stream monitoring stations was installed to record transient qualitative and quantitative effects. These monitoring stations were designed to continuously record pH, conductivity, and flow.

The locations of the stream monitoring stations are indicated in Figure 12. The monitoring instrumentation for each station was housed in a weatherproof-bulletproof enclosure which was mounted above a stilling well located upstream from the weir structure. A typical stream weir structure and monitoring station are illustrated in Figure 35. The monitoring station enclosure design is illustrated in Figure 36.

Initially, grab samples were collected on a weekly basis at each monitoring station. These samples were analyzed for pH, total iron, sulfate, turbidity, total acidity, alkalinity, and conductivity.

Samples were also collected at monthly intervals at both the stream monitoring stations and borehole discharges. These samples were analyzed for alkalinity, total acidity, conductivity, pH, turbidity, calcium, magnesium, sulfate, total iron, ferrous iron, total solids, suspended solids, dissolved solids, settleable solids, aluminum, and manganese.

Due to the relative inaccessibility and sporadic operation of the borehole discharge pumps, accurate pumping data was only available for the Snider and Six-Right borehole discharges.

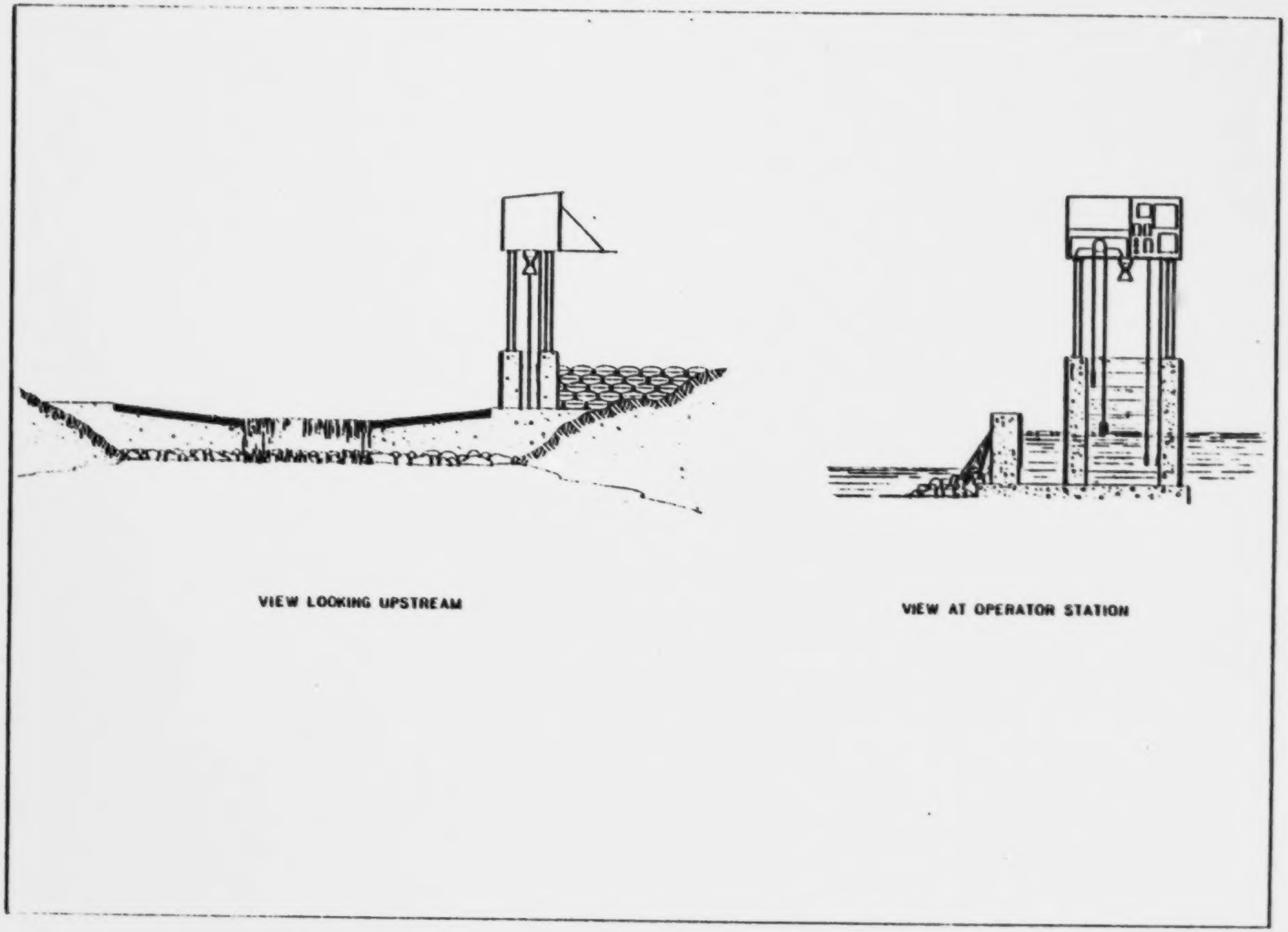

VIEW LOOKING UPSTREAM
VIEW AT OPERATOR STATION

Figure 35. Typical weir structure and monitor station.

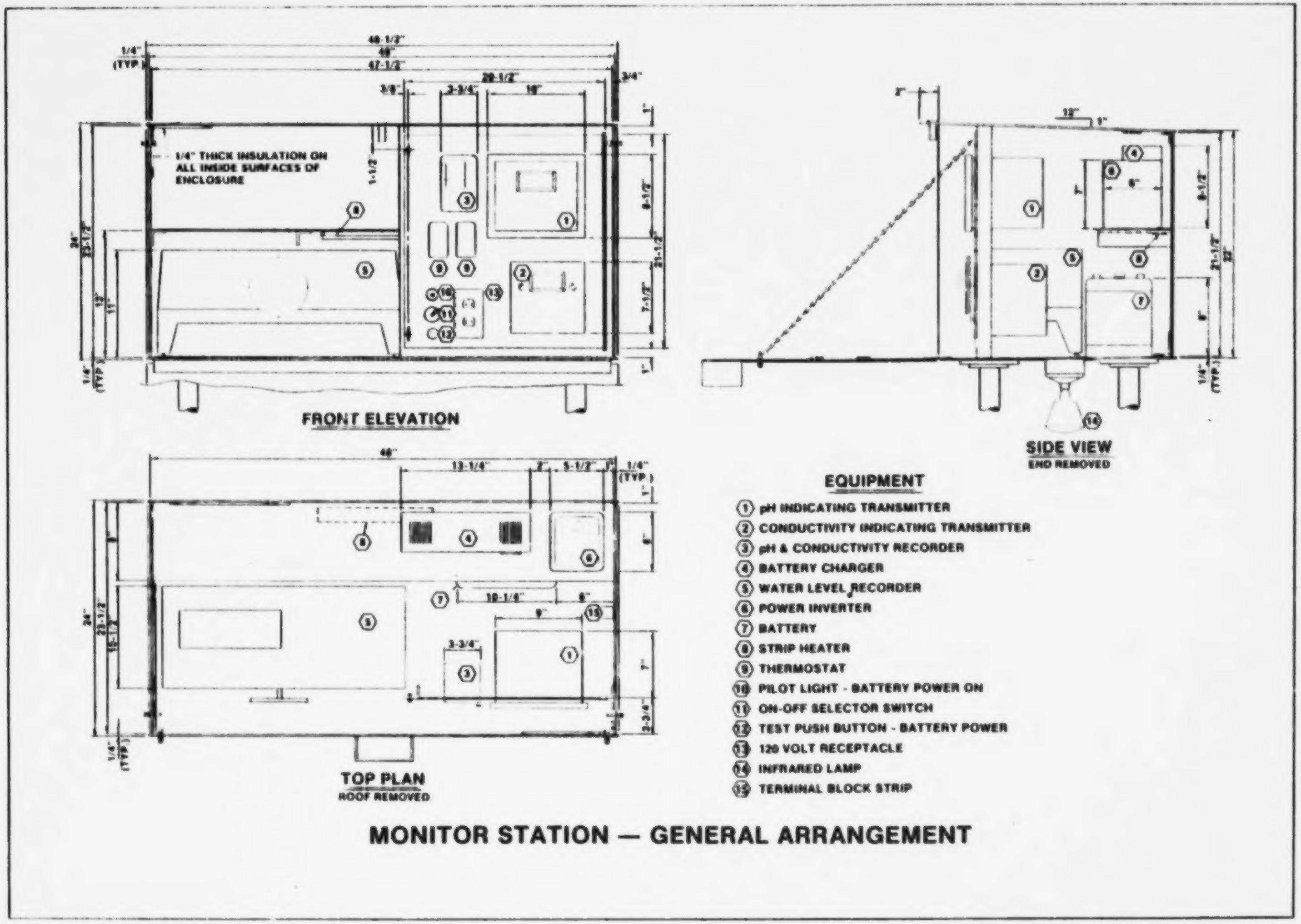

FRONT ELEVATION
1/4" THICK INSULATION ON ALL INSIDE SURFACES OF ENCLOSURE
SIDE VIEW
END REMOVED
TOP PLAN
ROOF REMOVED
EQUIPMENT
① pH INDICATING TRANSMITTER
② CONDUCTIVITY INDICATING TRANSMITTER
③ pH & CONDUCTIVITY RECORDER
④ BATTERY CHARGER
⑤ WATER LEVEL RECORDER
⑥ POWER INVERTER
⑦ BATTERY
⑧ STRIP HEATER
⑨ THERMOSTAT
⑩ PILOT LIGHT - BATTERY POWER ON
⑪ ON-OFF SELECTOR SWITCH
⑫ TEST PUSH BUTTON - BATTERY POWER
⑬ 120 VOLT RECEPTACLE
⑭ INFRARED LAMP
⑮ TERMINAL BLOCK STRIP
MONITOR STATION — GENERAL ARRANGEMENT
48-1/2"
48"
47-1/2"
1/4" (TYP.)
3/4"
20-1/2"
3/8"
3-3/4"
10"
1-1/2"
24"
23-1/2"
12"
11"
9-1/2"
21-1/2"
7-1/2"
1"
22"
6"
2"
13-1/4"
5-1/2"
10-1/4"
9"
7"
2-3/4"
19-1/2"

Figure 36. Monitor station - general arrangement.

In order to compensate for this data deficiency, weir plates and event recorders were installed at each of the borehole locations.

A float activated switch was installed on the weir plate to record the actual period the pump operated. This switch was connected to a Rustrak event recorder which operated from a six-volt battery. The flow over the weir was measured weekly and the total hours of pump operation was taken from the strip chart of the recorder.

These event recorders are designed to operate on a six-volt dry cell battery. However, six-volt motorcycle wet cell batteries were substituted since they could be recharged each week and would effect a cost savings to the project.

Due to the very acidic nature of the drainage discharged from these boreholes, the orignial carbon steel weir plates were rapidly corroded and required frequent maintenance or replacement. Although constructed of 1/4" steel plate and treated with automotive undercoating, the weirs often lasted less than one month in this corrosive environment. This problem was later resolved by substituting weirs constructed of marine plywood and coated with fiberglass to help protect against separation from freezing.

Each discharge was measured weekly for flow using either the weir or a Parshall flume. The only exception was the Snider borehole which was rated by pump discharge through a horizontal pipe flowing full. This flow was calculated using the formula:

$$q = 3.61\ AX\sqrt{Y}$$

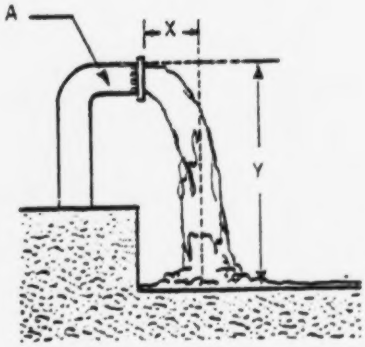
Where:

q = Discharge in gallons per minute

A = Inside cross-sectional area of the pipe, in square inches

X = Distance from the end of the pipe and along the axial projection of the top inner pipe surface, to where point Y is measured, in inches

Y = Vertical drop of the surface of the discharging stream below the extension of the inside top of the pipe, in inches, measured at a selected value of X



By correlating pumping time with measured flow rates, project personnel were able to establish a good baseline of mine water discharge volumes upon which to evaluate the effectiveness of subsequent reclamation efforts.

At this same time a recording rain gauge was installed near monitoring stations 8 and 9. These stations are close to the center of the watershed. This was done to double-check possible localized storms affecting the Dents Run watershed which were not recorded at the U.S. Weather Bureau Station in Morgantown. It was determined that throughout the study the variances between these two weather stations were insignificant.

All recording charts were to be collected at weekly intervals and the information from these charts and from periodic water sample analyses were to be tabulated and a program developed to transmit the data to the Environmental Protection Agency in a format compatible with the Industrial Environmental Research Laboratory's computer facilities.

The stream monitoring stations were to operate from a primary 120 volt AC source supplied from local utility lines. In the event of a power failure of this primary system, a standby battery power source was to be automatically activated. The battery circuit also had provisions for testing during routine service inspections.

In order to eliminate an excessive drain on the battery, the heat lamp and strip heater did not operate on the battery circuit. The battery had the capability of powering the instruments continuously for a period of approximately 20 hours. The battery also had the capability of providing power for a period of approximately six days if operated on a cycled sequence of two minutes every fifteen minutes. When this circuit was operating from the primary source, the battery charger would recharge the battery to its full capacity and shut off automatically. The power and control functions were to be automatically switched back to this source when the primary power was restored.

To facilitate stream flow measurements, weirs were designed for monitoring stations 1, 2, 3, 4, 6, and 7, and a self-cleaning Parshall flume was to be installed at monitoring station 9. The design of these stations was completed during the summer of 1972 and construction of the stream monitoring stations was completed during the late fall of 1972.

Until this time, all work efforts were proceeding according to original estimates and without any significant problems. However, several problems began to develop at about the completion of stream monitoring station construction. The foundation for monitoring station number one was apparently not constructed on stable bedrock and consequently settled on one side, resulting in an obviously skewed weir plate which could not be reliably used for flow measurements. In addition, piping beneath the weir foundation quickly eroded streambed materials resulting in a situation where the bulk of the flow (under normal conditions) passed under, rather than over, the weir structure. For all intents and purposes, this made monitoring station number one useless as a flow measuring device.

In the meantime, intense storms combined with road construction on Interstate 79 resulted in severe sedimentation behind the weir structure at monitoring station number 2. The volume of debris and rock accumulated was so massive that manually cleaning the structure was impossible in its filled-in condition; monitoring station number 2 was unusable as a flow measuring device.

The contractor who installed the weir structures made an error at monitoring station number 7 and poured the base two feet higher than the design specifications indicated. This, in turn, raised the pool elevation by two feet, which backed up water into the basement of a nearby home during storm events and placed a small footbridge underwater. Consequently, the contractor was required to install a sump pump in the basement of the home and construct a new, elevated footbridge.

Generally, the discharge from the Snider borehole, although extremely high in ferrous iron, was alkaline in nature. As this water was pumped to the surface and aerated by cascading over natural drops in the drainage channel, the ferrous iron was easily converted to the ferric state since the higher pH accelerated this conversion. In the ferric form, the iron quickly settled out in any quiescent pool, creating thick deposits of yellowboy sludge. Unfortunately, the pools created by the weir structures acted as very effective settling ponds and rapidly impounded large volumes of mine drainage sludge. In addition to a severe maintenance problem, this condition also resulted in aesthetic degradation of the stream channel in the immediate vicinity of the station. The "aesthetic degradation" referred to here should not be overrated, as Dents Run was a visual nightmare at the inception of this project. It was polluted throughout most of its length with acid mine drainage, yellowboy sludge, trash and debris, and untreated sewage. The weirs simply concentrated some of the already present pollution.

Within a short period after the stations were installed, all weirs and stilling wells filled with silt and debris. Station 9, the Parshall flume, was the only station which was not silted beyond use. The build-up behind the weirs consisted of rock 15 to 20 cm (6 to 8 inches) in diameter down to clay mud. The average depth of material behind the weirs was 38 cm (15 inches). It was estimated that material would have to be removed one time per month in summer and two times per month in winter in order to obtain reasonably accurate flow records using the stated discharge rating of the weirs. The job was advertised for bids and the lowest bid received was for $14,000 for a one-time cleaning. A one-year cost to keep the weirs clear of silt would have been $266,000, based upon bids received at the estimated cleaning frequency. It was decided that this cost of maintenance was unreasonable and prohibitive for the collection of data that could be gathered by other methods.

While discussing the stream monitoring stations it would be well to discuss the monitoring station instrumentation. It was originally proposed to equip each monitoring station with pH, conductivity, and stage level analyzers utilizing a dual trace recorder for the former two parameters and an integral recorder for the latter. Each station was supplied with 110 AC power with a 12-volt battery and power inverter as a backup source in the event of commercial power failure.

The pH and conductivity electrodes were cleaned weekly with a hydrochloric acid solution (1:1 dilution) to remove the iron sludge collected on and in the electrodes. The stage level recorders were never used because of the previously mentioned silt problems.

The dual channel (single pen) recorders worked well during the project period, although some interaction between the pH and conductivity recordings was experienced at some stations at various times during the project.

Each conductivity analyzer functioned perfectly during the project period. Unfortunately, the pH analyzers did not function well. Several problems were encountered with the analyzers and their large sensor units. The pH analyzers and electrodes proved to be designed for a non-hostile environment. The sensors incorporated a preamplifier unit which was to send a stronger signal to the analyzer. Because of this unit, an oversized 5-position terminal block, large plastic body on the glass electrode and an excessively large capacity reference cell caused this sensor to be approximately the size of a one liter (one quart) canning jar. With such a large senor housing, leakage would occur around the closure system despite numerous attempts to obtain a water-tight seal. Due to the large size of the sensor, moisture would condense on the internal surface of the unit during climatic changes. Rust and corrosion soon took their toll and parts replacement became the "order of the day." When the analyzer electronics began to burn out, it was decided to abandon the pH analyzers and continue the conductivity recording.

The pH conductivity stage level/recording system cost $81,300, including the weirs, and yielded practically no usable data. When this cost is added to the aforementioned silt removal cost, the monitoring program for this project would have exceeded the cost of reclamation. Also, these costs do not consider the $50,600 spent on laboratory analysis of the water samples collected.

In the meantime, as the problems plaguing the monitoring stations were being worked out, the engineering design specifications for the reclamation of the Priority 1 mine sites were being completed, reclamation contracts were being awarded, and reclamation regrading was being initiated. Although numerous problems had developed with stream monitoring stations, the project was generally proceeding according to schedule and the monitoring phase was providing the data necessary to evaluate the effectiveness of the program.

From an evaluation standpoint, this is where significant problems began to develop. One of the most significant problems evolved around Consolidation Coal Company's water handling practices. At the onset of this project, the original premise was that the borehole discharges would be available throughout the duration of the study in order to evaluate the control practices employed. As part of the watershed cleanup master plan, Consolidation Coal Company was to construct a number of mine drainage treatment plants to provide adequate treatment of any water discharged to Dents Run from their workings. Consolidation Coal Company's intention was to combine several of the discharge points underground in order to minimize the number of surface treatment facilities required.

The original plan called for three mine water treatment facilities in the watershed: the Loar Treatment Plant was to be constructed first and was to treat the drainage from the Laurel Point and Loar borehole discharges. This facility was to be constructed at the location of the Loar borehole and water from the Laurel Point was to be transferred underground at this point. The second plant was to be installed near the Snider borehole discharge and was to treat the water from the Snider and Six-Right boreholes. The third and final plant was to combine the Hess and Valotto borehole discharges. Original plans called for this facility to be constructed at the Hess discharge point.

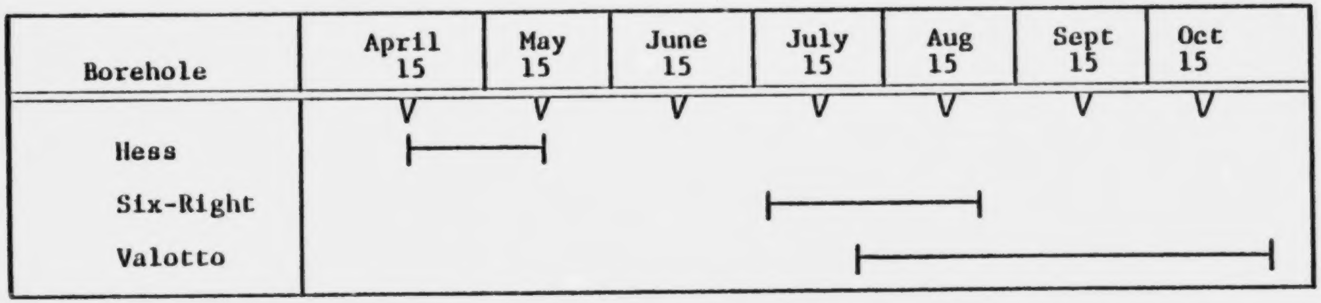
Initially, these plans proceeded pretty much in compliance with the original schedule. The Loar treatment plant was constructed and put into operation and water from the Laurel Point borehole was successfully transferred underground to this point. By this time, Consolidation Coal Company's plan for subsequent treatment facilities was fairly common knowledge throughout the watershed. Asking prices for land in the vicinity of the borehole discharge points quickly increased. In one case, a landowner set a price of $15,000 per acre for a 12 acre tract of rural farmland/woodland that several years before had sold for less than $100 per acre. Under these circumstances, Consolidation Coal Company began considering alternatives.

One alternative that seemed particularly attractive to Consolidation Coal Company was the possibility of transferring water underground to a location in the Indian Creek watershed just west of the Dents Run watershed. This property was owned by the Consolidation Coal Company and was adjacent to the Snider farm in Dents Run. Consolidation Coal had already developed plans for construction of a large treatment plant at this location (hereafter referred to as the Sears Farm). After intensive geologic study, Consolidation Coal Company concluded that it was possible to intercept the swag into which water from the Snider borehole discharged and divert that water to the Sears Farm.

At this point (early 1973), Consolidation Coal started to experiment with the Hess, Valotto, Six-Right, and Snider discharges to determine which flows could be transferred efficiently. Numerous approaches were investigated such as transferring the Hess and Valotto drainage to the Six-Right to Sewickley coal seam to Snider discharge pump, Six-Right and Snider to the Sears Farm, and various combinations of these alternatives. Each alternative was tested independently by introducing a dye tracer and then determining whether or not the water could actually migrate to the Snider discharge point. The reported approximate schedule of this testing is presented in Table 5, although visual observation during this period would suggest that the actual testing program was considerably more extensive than this schedule indicates.

As far as the demonstration project was concerned, two unfortunate events evolved from this experimentation: (1) when water was tranferred to the Sears Farm, it was combined with an undetermined volume of water from sources outside the Dents Run watershed, and (2) Consolidation Coal personnel

TABLE 5. SCHEDULE OF BOREHOLE DIVERSION TO SEARS FARM, 1973



This schedule is for the temporary transfer of the borehole discharge to the Sewickley coal seam to determine if it would migrate to the Snider/Sears Farm pool. It was determined that each would migrate to this point where it could be picked up for treatment.

All three boreholes were permanently diverted by the end of December 1974 and the Snider pump was shut off. All borehole discharge water was then picked up by the Sears Farm treatment plant pump.

failed to advise project personnel of the water handling investigations in progress so that compensating data could be collected. Consequently, the data base essential to accurately evaluate the effectiveness of the reclamation efforts was, at very best, questionable and could not be segregated with any degree of certainty.

It must be stressed that, although unfortunate from a project standpoint, Consolidation Coal had little option but to pursue the course of action undertaken. They were legally required to treat their mine water discharges in order to comply with State water quality criteria, and, at the same time, were facing exorbitant property prices. The unfortunate fact is that there was not more communication between project personnel and Consolidation Coal personnel in designing and evaluating the water handling schemes involved.

SECTION 8

RECLAMATION SPECIFICATIONS

The reclamation plans and specifications for each area reclaimed were prepared by the Cyrus Wm. Rice Division of NUS Corporation, who also performed the feasibility study for this project. The plans and specifications were advertised for bid as they were received from the consultants. Contracts were awarded on Priority I jobs (with the exception of Section G, strip J) on October 1, 1972. The Priority II contracts were awarded on September 1, 1973.

The plans and specifications were prepared for bidding on a total disturbed area basis rather than on a cubic yard of materials to be moved basis. All contract awards for work on this project and for major equipment purchases were by competitive bid and were supervised by the West Virginia Department of Finance and Administration.

The bid specifications for the Priority I jobs required mulching on all slopes exceeding a 15 percent grade. In the Priority II specifications, this was changed to require mulching of all disturbed areas. Better seeding results were achieved because of this change.

Reclamation work within the watershed was primarily of the contour and pasture type backfills (Figures 14-A and B) depending upon the condition of the highwall at each site. The pasture type backfill was used in areas where the highwall was relatively sound and the contour backfill was used where the highwall was highly fractured. In each case, the backfills were compacted in order to prevent excessive infiltration into the intercepted deep mine workings and auger holes.

Site investigations during the feasibility study indicated that the majority of the surface mines had intercepted deep mine workings, highwalls were highly fractured, and surface water runoff in these areas was usually directed into the deep mine workings.

Several of the surface mines contained water impoundments in portions of the unreclaimed pit. As the reclamation work required draining these impoundments, portable treatment facilities were employed to provide adequate treatment of the impounded water prior to discharge to a receiving stream.

Conventional heavy construction equipment was used in the regrading of the surface mines, conventional farm equipment was used in the surface preparation, and seeding, mulch, and fertilizer were applied by hydroseeder. Compaction of the backfill in the area of auger mined highwalls was done using a conventional 55-ton roller used in highway construction. A minimum of 10 passes was made with the roller. The reclamation specifications called for the placement of impervious material in maximum 61 cm (2 feet) lifts in the area from the base of the highwall a minimum of 6 meters (20 feet) vertically, and at least 3 meters (10 feet) above any auger holes or mine openings. Where impervious material was not available, the contractor was to use the best material available. This material was to be free of rocks and debris.

The cost of reclamation cited under each work area description is the cost of labor, equipment, and materials to perform the tasks required.

Regraded spoil materials were tested at the West Virginia University Soil Testing Laboratory before and after reclamation. Soil samples were tested for texture, drainability, chroma, pH, calcium, magnesium, phosphorus, potassium, and sulfur. Based upon the results of these analyses, recommendations for fertilizer, lime, seeding, and mulching were provided by the Soil Conservation Service of the U.S. Department of Agriculture. These recommendations are included at the end of each of the following site descriptions. Some of the information presented in these descriptions is repetitious of information presented earlier, but is included here for the reader's convenience.

SECTION 9

DETAILED SITE DESCRIPTIONS

SECTION C - STRIP AREA C (PRIORITY I)

The total length of this strip area is approximately 792 meters (2,600 feet), the width of the bench varies from 30.5 meters (100 feet) to 46 meters (150 feet). The condition of the highwall was very solid. There were no drift mine interceptions but the area had been very extensively auger mined. The auger mining was to the dip in this area, therefore, allowing all surface drainage to enter these auger holes.

Reclamation work at the site included earth compaction seals in each auger hole to prevent surface water infiltration. This compaction was carried out for a distance of 3 meters (10 feet) above the auger holes. Spoil material was then brought up from the outslope and placed in normal backfilling methods to reduce the highwall height to 9 meters (30 feet) or less, then graded to a pasture backfill.

After the surface was brought to the required contour, the final drainage pattern was established. The contractor was required to select the shortest possible distance for carrying the water from within the construction limits and taking advantage of any natural drainways that existed to dewater the contract area. A diversion ditch 774 meters (2,540 feet) long was constructed along the outer edge of the bench and the water directed to a natural drainage area about midway of the reclaimed strip area.

Upon completion of regrading, soil samples were collected for analysis by the West Virginia University Soil Testing Laboratory. Liming and fertilization were completed in accordance with these tests. Seeding and tree planting were completed according to the following recommendations by the Soil Conservation Service:

Ground Agricultural Limestone	4.4 M.T./ha	(2 T/acre)
Fertilizer (10-10-10)	897 kg/ha	(800 lbs/acre)
Seeding: Tall Fescue	22.5 kg/ha	(20 lbs/acre)
Red Top	3.5 hg/ha	(3 lbs/acre)
Birdsfoot Trefoil	11 kg/ha	(10 lbs/acre)
Mulch: Straw or Old Hay	4.4 M.T./ha	(2 T/acre)

The limestone and fertilizer were worked into the soil by disking. The mulch was applied with 378 liters (100 gallons) per acre of asphalt emulsion on all areas exceeding 15 percent slope.

The cost of reclamation of strip area C was $11,500.00, which is $1,645.00 per hectare (ha) ($4,060.00/hectare) for 2.83 ha (7 A). Individual item costs were:

Backfilling and Grading	$8,109.00
Agricultural Limestone	280.00
Fertilizer	220.00
Seeding	1,771.00
Mulching (slopes exceeding 15 percent grade)	1,120.00

One year after planting, a highly acceptable grass cover was present. During and after the second growing season two profitable hay crops per year were expected from this and the adjacent strip area. The adjacent strip area (B) is discussed under Priority II reclamation.

Trees were planted on the outslope according to the Soil Conservation Service planting plan. The trees were planted in six row bands on a 2.5 meter (8 foot) grid. Trees planted were European Black Alder, Black Locust, and Sycamore. All trees planted survived the first two winters and appeared to be doing well at an inspection in early winter, 1978.

Unfortunately, the landowner of this area and the adjacent strip area (B) signed an agreement with a timbering operation to have the timber removed from an adjoining site. The timbering operation used the access road created on these reclaimed strip benches as a haulage road, creating large ruts, destroying much of the vegetative cover, and significantly increasing erosion. The degradation created by this operation was still readily apparent at a site inspection in mid-December 1978. Figure 37 shows Section C, strip area C after reclamation.

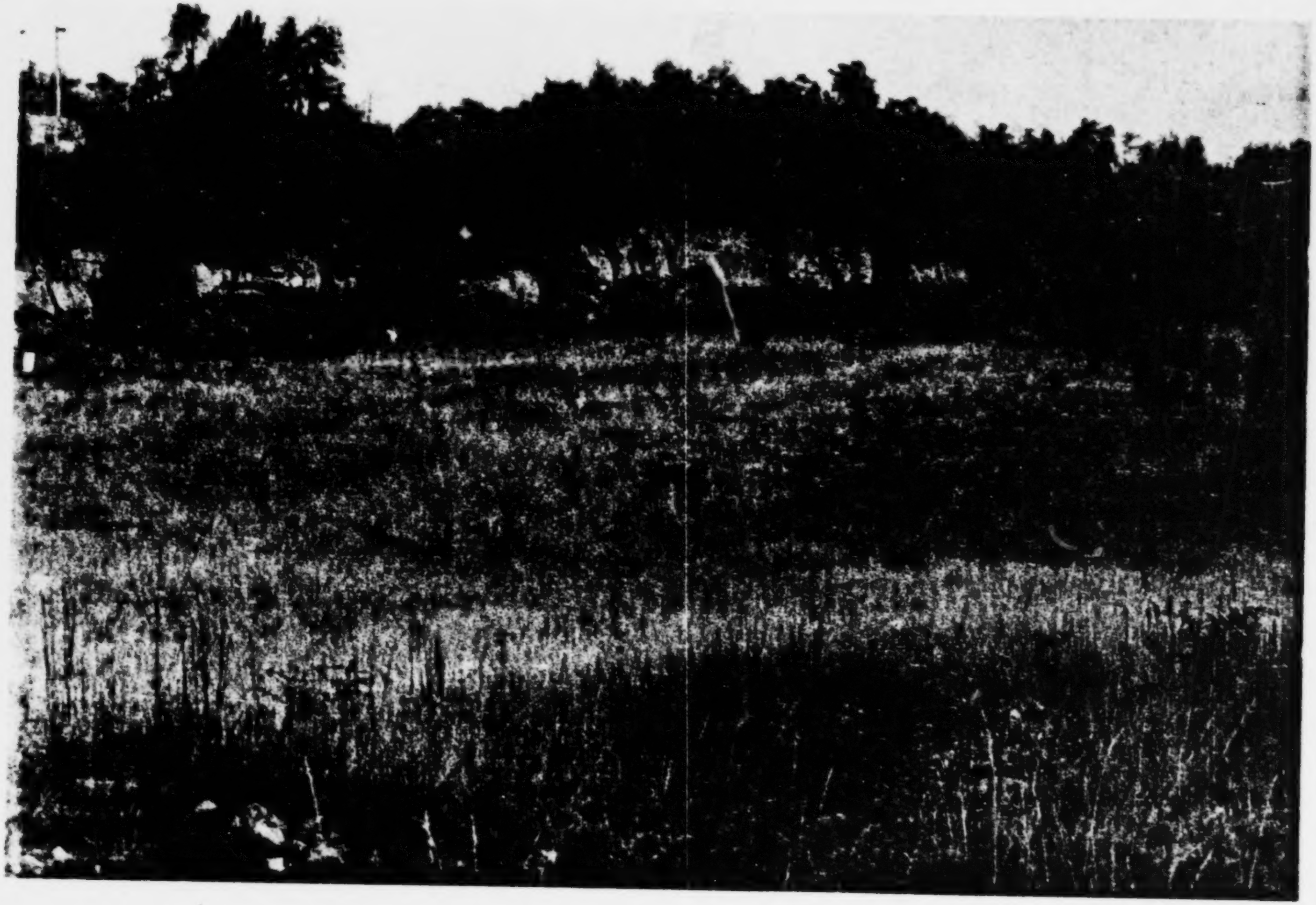


Figure 37. Section C, Strip area C after reclamation.

SECTION G - STRIP AREA A (PRIORITY I)

The total length of this strip area is 457 meters (1,500 feet), the width of the bench is approximately 38 meters (125 feet). The exposed height of the highwall was 9 meters (30 feet) and was generally highly fractured. The fracture zone ran at a 45 degree angle to the highwall and extended back approximately 15 meters (50 feet). There was extensive auger mining in the strip area. Where these auger holes were exposed at low points on the mine bench, there were high water marks about half way up on the inside walls of the auger holes. In addition, drainage patterns established over the mine bench indicated that large volumes of drainage were being directed into many of the auger openings during storm events or snow melts. Examination of available underground mine mapping indicated a direct connection between this mine site and the underground workings at Strip C, Section G. Based on this information, it was believed that much of this water found its way into underground mine workings in that area.

Reclamation in this are was performed under the same bid specifications as strip area C in Section C. The original backfill was excavated at the base of the highwall to expose the auger openings. A clay compacted backfill was placed in front of the auger holes and spoil was regraded to a pasture backfill. In addition, the fracture zone was sealed and compacted with the best available material. A water diversion ditch was placed so as to convey surface runoff around this area. A diversion ditch approximately 400 meters (1,312 feet) long was placed near the outslope to carry the surface runoff to a natural drainage area over the slope. About 9 meters (30 feet) of the outslope was riprapped with stone to prevent erosion. The Soil Conservation Service recommended fertilizer and seeding rates of:

Ground Agricultural Limestone	4.4 M.T./ha	(2 T/acre)
Fertilizer (10-10-10)	897 kg/ha	(800 lbs/acre)
Seeding: Tall Fescue	22.5 kg/ha	(20 lbs/acre)
Red Top	3.5 kg/ha	(3 lbs/acre)
Birdsfoot Trefoil	11 kg/ha	(10 lbs/acre)
Mulch: Straw or Old Hay	4.4 M.T./ha	(2 T/acre)

The limestone and fertilizer were worked into the soil by disking. Mulch was applied with 378 liters (100 gallons) per acre of asphalt emulsion on all outslopes and drainage ditches.

The grass cover achieved here after two growing seasons did not meet State standards for reclamation vegetative cover. The standards for evaluation of ground cover are from the West Virginia Surface Mining Regulations, Series VII, 1971, which required at least 80 percent cover of legumes and perennial grasses. Bare areas were not to exceed one-fourth acre (100' x 100') in size nor more than 20 percent (20%) of the area seeded. The State Reclamation Division had planned to reseed this area and apply a mulch cover in an attempt to achieve adequate cover. However, a site inspection conducted in mid-December 1978 indicated that little, if anything, had been done to the site in the form of preventative or routine maintenance since the project reclamation completed in 1973 (Figure 39).

The cost of reclamation of strip area A was $23,700. This is $5,850 per ha ($2,370.00/A) for 4.05 ha (10 A). Individual item costs were:

Backfilling and Grading	$18,855.00
Agricultural Limestone	400.00
Fertilizer	315.00
Seeding and Planting	2,530.00
Mulching (slopes exceeding 15 percent grade)	1,600.00

SECTION G - STRIP R (PRIORITY I)

In an earlier section, this site was divided into two separate areas, an east and a west section, in order to simplify the pre-reclamation characterization. However, since the reclamation scheme approached this mine as a single site, the following discussion does not differentiate between the two sections of the mine.

The total length of this surface mine was approximately 457 meters (1,500 feet) with a bench width that varied from 15 to 76 meters (50 to 250 feet). The highwall was highly fractured and averaged 12 to 15 meters (40 to 50 feet) in height. The area had been almost totally undermined by augering. It was suspected that many of the auger holes had cut into old drift mine workings developed from the opposite side of the mountain. This extensive mining activity left the highwall supported by small pillars of coal which were giving way and causing considerable fracturing subsidence.

This strip area had a water impoundment against the highwall containing an estimated 851.6 cu. meters (225,000 gallons) of highly contaminated water: total acidity 4,200 ppm; pH 2.3; total iron 1,100 ppm; sulfates 5,100 ppm; and a conductivity of 4,100 micromhos. This water had to be treated and discharged to a receiving stream before reclamation could begin.

Indications were that there was a direct connection between the auger openings and abandoned underground workings at this site and underground mine opening 38 in strip area M, Section G. Just prior to reclamation operations on strip area R, project personnel measured the flow from mine opening 38 at 2,500 gallons per minute shortly after a storm. In addition to the large volume, it was also noted that this discharge was turbid on several occasions following storm events. Average flow conditions here ranged between 400 and 500 gallons per minute during the winter and spring months to no discharge during July and August. Although both pre- and post-reclamation monitoring were really inadequate to substantiate any valid conclusions, measurements taken shortly after the reclamation was completed seemed to indicate a reduction in flow. Three measurements were taken in the late fall of 1973 and all measurements shows a flow of less than 250 gallons per minute, despite relatively high precipitation preceding these flow estimates. A flow measurement made on December 17, 1978, indicated flow at that time of approximately 300 gallons per minute.

It was apparent that this was going to be the most difficult area of all to reclaim. The area contained a number of massive sandstone boulders. With the possible exception of a small amount of material above the highwall, there was virtually no topsoil available at this site for a top dressing. Clay-like material was totally non-existent for sealing the auger openings. Regrading was accomplished in accordance with the plans and specifications using a compacted backfill of the best available material against the auger holes. A contour backfill was then effected by grading the spoil to a moderate slope against the highwall and then pushing down material above the highwall and distributing the earth present. A water diversion ditch 400 meters (1,300 feet) was placed at the outer edge of the reclaimed bench and water was directed off of the area at the extreme western end where a natural drainageway already existed.

The surface mine was seeded with little hope of success. Although a sparse cover of grasses was accomplished, it fell far short of State regulations (Figures 38 and 39). It was hoped that, with time, the sandstone would weather and a suitable medium would be provided for natural revegetation. An excellent growth was achieved on the eastern section of this area. A site inspection conducted in the early winter of 1978 indicated that the area had received little or no maintenance since the original reclamation work was completed. Consequently, vegetative cover was sparse and a number of erosion gullies had developed.

Figure 38. Vegetative cover at surface mine, Section G, Strip R.

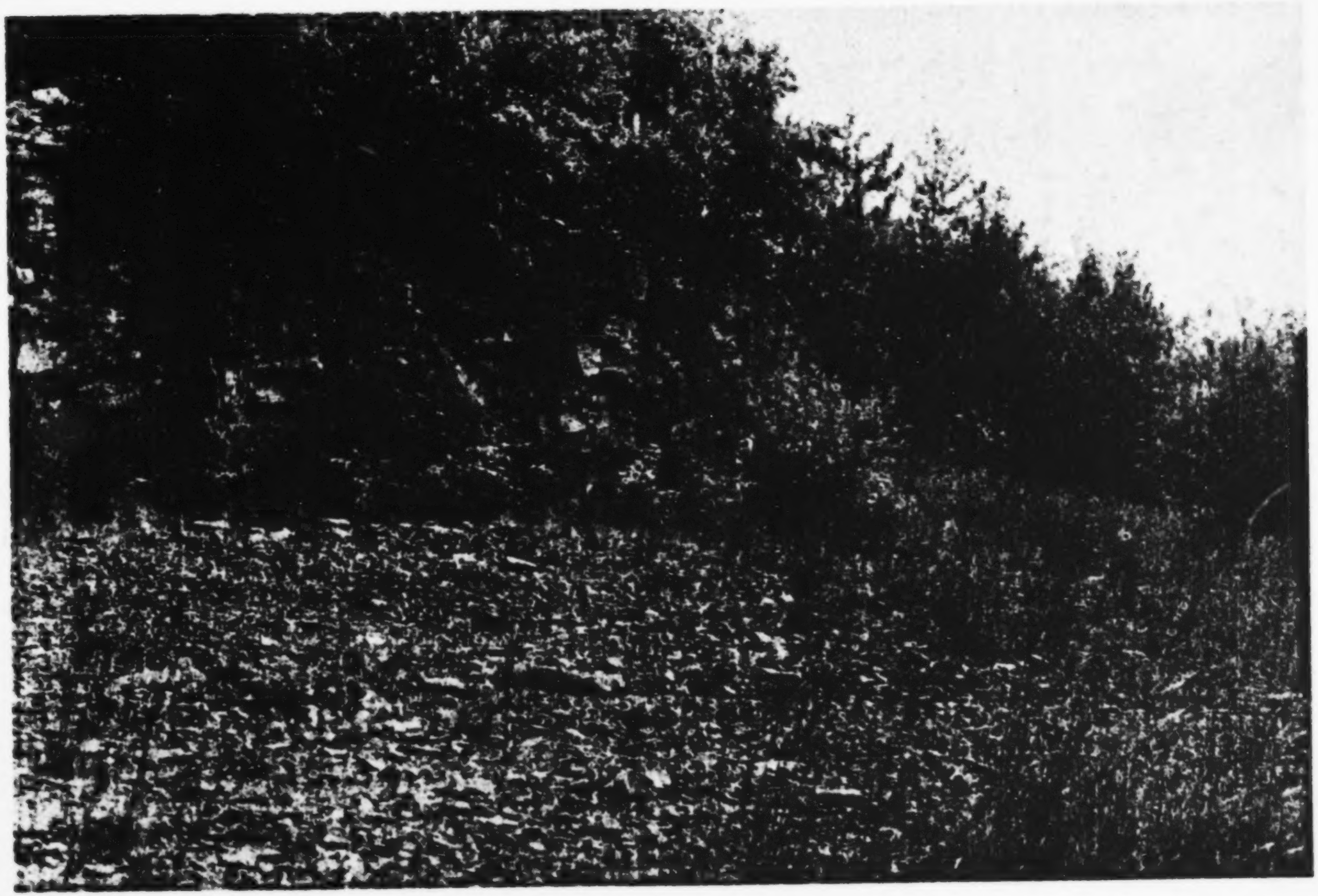


Figure 39. Vegetative cover at surface mine, Section G, Strip R.

Surface preparation and revegetation recommendations by the Soil Conservation Service were:

Ground Agricultural Limestone	4.4 M.T./ha	(2 T/acre)
Fertilizer (10-10-10)	897 kg/ha	(800 lbs/acre)
Seeding: Tall Fescue	22.5 kg/ha	(20 lbs/acre)
Red Top	3.5 kg/ha	(3 lbs/acre)
Birdsfoot Trefoil	11 kg/ha	(10 lbs/acre)
Mulch: Straw or Old Hay	4.4 M.T./ha	(2 T/acre)

The limestone and fertilizer were worked into the soil by disking. The mulch was applied with 378 liters (100 gallons) per acre of asphalt emulsion on all areas exceeding a 15 percent slope.

The cost to reclaim strip area R was $64,050.00. This is $9,900.00 per ha ($4,003.00/A) for 6.47 ha (16 A). Individual item costs were:

Backfilling and Grading	$56,298.00
Agricultural Limestone	640.00
Fertilizer	504.00
Seeding and Planting	4,048.00
Mulching (slopes exceeding 15 percent grade)	2,560.00

SECTION C - STRIP B (PRIORITY II)

The total length of this surface mine area is approximately 792 meters (2,600 feet). The bench width varied from 38 meters (125 feet) to 61 meters (200 feet) with a highwall height from 11 meters (35 feet) to 15 meters (50 feet). The surface mine had never been backfilled and there was considerable acidic material present on both the bench and the outslope. There were three ponded areas on this strip mine, each averaging approximately 15 meters (50 feet) wide by 61 meters (200 feet) long. The condition of the highwall varied from very firm in some areas to highly fractured in other areas. There was one drift mine entry in the extreme southern section of the strip area. Although the roof of this mine had collapsed, the only evidence of its existence was a small amount of seepage. This strip area was actually a continuation of strip C discussed earlier under priority I and was reclaimed under the same contract.

All acid producing material was buried and pasture backfill was employed with a compacted backfill in front of the one deep mine entry. Revegetation after liming and fertilizing used Tall Fescue, Red Top, and Birdsfoot Trefoil in the same mixture as strip C as well as European Black Alder, Black Locust, and Sycamore planted on the outslopes (Figure 40).

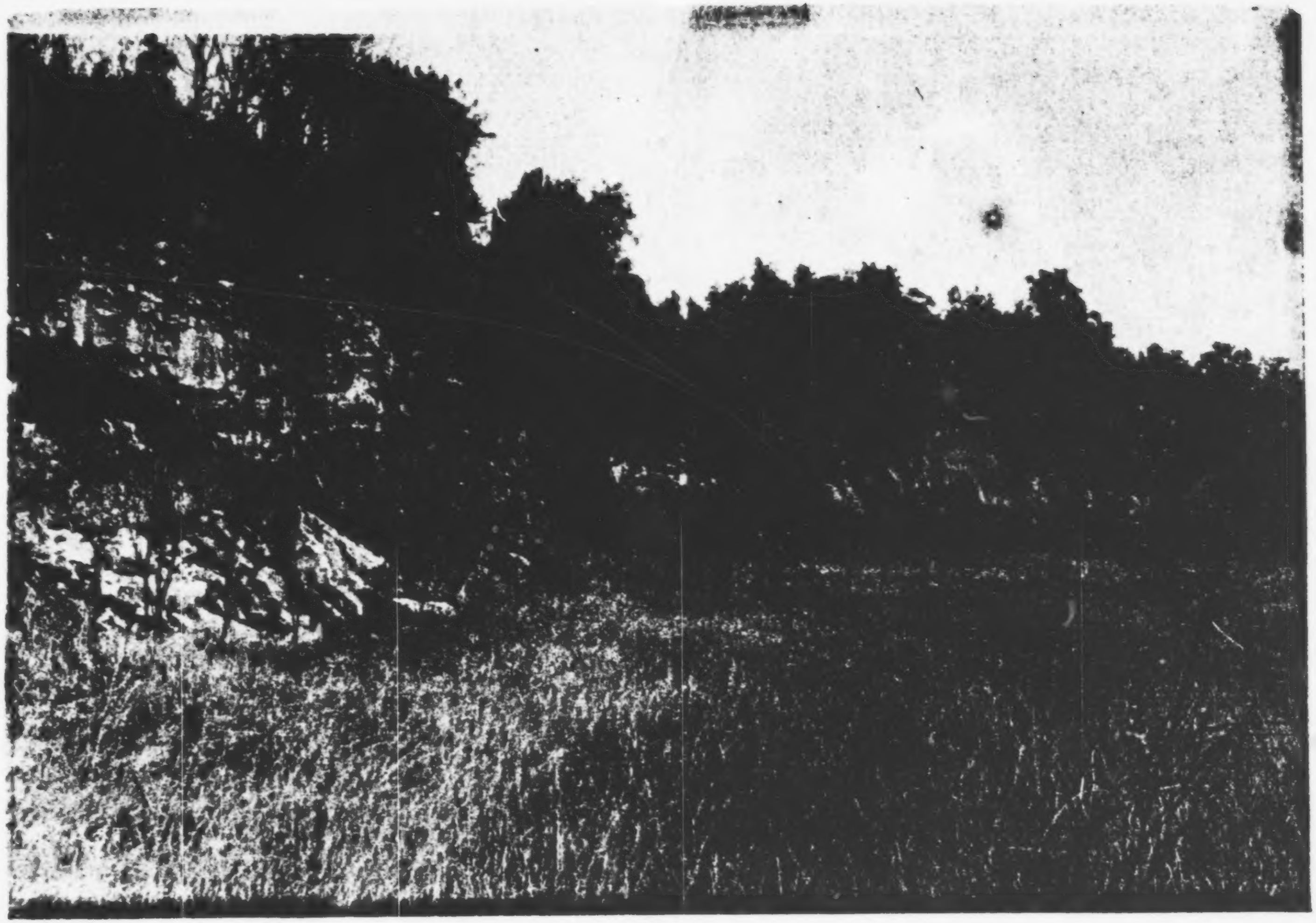


Figure 40. Revegetation, Section C, Strip B.

Reclamation costs of strip B were $93,750.00. This is $9,280.00 per ha ($3,750.00/A) for 10.1 ha (25 A). Individual item costs were:

Backfilling and Grading	$81,638,00
Agricultural Limestone	1,000.00
Fertilizer	787.00
Seeding and Planting	6,325.00
Mulching (slopes exceeding 15 percent grade)	4,000.00

SECTION C - STRIP H (PRIORITY II)

The length of this strip area is approximately 610 meters (2,000 feet) and the bench width varies from 23 meters (75 feet) to 46 meters (150 feet). The height of the highwall in strip area H varies from 4.6 meters (15 feet) to 11 meters (35 feet). There are three drift mine entries into the highwall of the central and western portions of the strip area (drift mines 11, 12, and 13) although the highwall is solid with a minimum of fracturing. All of these entries were apparently worked to the dip and, therefore, any drainage would be into the mine rather than out of the mine. The mine openings are approximately 1.5 meters (5 feet) high by 3.6 meters (12 feet) wide.

This strip area was reclaimed by burying all acid producing material, compacting the backfill in front of the deep mines, and regrading to a contour backfill. A diversion ditch was placed on top of the highwall. The following preparation and seeding plan, as recommended by the Soil Conservation Service, was implemented:

Lime		11 M.T./ha	(5 T/acre)
Fertilizer (10-20-20)		560 kg/ha	(500 lbs/acre)
Seeding:	Tall Fescue	33.6 kg/ha	(30 lbs/acre)
	Red Top	11 kg/ha	(10 lbs/acre)
	Birdsfoot Trefoil	3.4 kg/ha	(3 lbs/acre)

Straw mulch was placed at a rate of 4.4 metric tons/hectare (2 T/acre) on all disturbed areas. This strip mine area is 2.83 ha (7 A) giving a total area reclamation cost of $17,185.00 which is $6,070.00/ha ($2,455.00/A). Individual item costs were:

Backfilling and Grading	$14,700.00
Agricultural Limestone	140.00
Fertilizer	280.00
Seeding and Planting	665.00
Mulching (all disturbed areas)	1,400.00

Although seeding of the area was done in early October, a high risk period, an excellent ground cover was established during the first growing season. Unfortunately, little or no reseeding or routine maintenance was conducted after the initial reclamation work was completed. At an inspection on December 17, 1978, it was noted that the vegetative cover had thinned somewhat and a number of small erosion gullies had started to develop. Considering the length of time that the site had been unattended, however, the vegetative cover was doing quite well.

It was also noted during the 1978 inspection that this site and the adjacent mine site (strip area J) were being used as a garbage dump by some local residents. This could have been predicted since the area was a convenient and frequently used dumping ground before reclamation.

SECTION C - STRIP J (PRIORITY II)

The height of the highwall in strip area J varies from 4.6 meters (15 feet) to 11 meters (35 feet) and the width of the bench averages approximately 61 meters (200 feet). The length is approximately 488 meters (1,600 feet). The condition of the highwall varied from solid in the eastern portion to highly fractured in the western portion. The western portion of the strip area has been backfilled to provide work area for the development of deep mining operations. There are three drift mine openings (14, 15, and 16) in this portion of the mine site. The mouths of openings 14 and 15 were still open; however, the roof had collapsed a short distance behind the mouth of the mine. Mine opening 14 was the only opening with a water discharge (7.5 liters per minute or 2 gallons per minute). In addition to these drift mine openings, there were several openings in the western portion that appeared to be deep mine interceptions during a later stripping operation. These openings were all collapsed. Due to the extremely fractured nature of the highwall (and subsequent subsidence), it was not possible to install any type of water seal that would be effective. There was an actively burning refuse dump north of drift opening 15. This dump was approximately 15 meters (50 feet) long by 15 meters (50 feet) wide and 9 meters (30 feet) high.

This mine site was regraded to a contour backfill. The draining drift mine openings were closed by pushing large rock into the openings, thus allowing the drainage to continue. This was necessary due to the highly fractured nature of the material over the mines. During regrading, this material became even more broken due to the weight of the dozer; regrading and compacting efforts had to be abandoned over the mines. The refuse material was worked into the backfill as depicted in Figure 41, extinguishing the fire and sealing the acid producing material from further leaching by water infiltration.

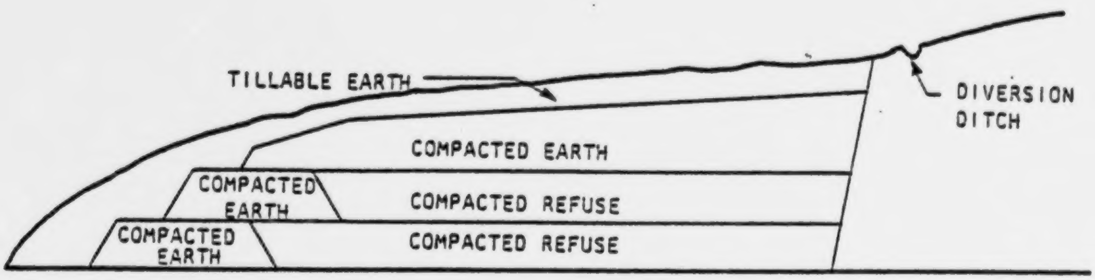

TILLABLE EARTH
DIVERSION DITCH
COMPACTED EARTH
COMPACTED EARTH
COMPACTED REFUSE
COMPACTED EARTH
COMPACTED REFUSE

Figure 41. Typical section of refuse - earth backfill.

A rock lined drainage ditch 100 meters (328 feet) long was installed over the regraded outslope to the toe of the spoil area from the drift mine openings. This drainage ditch also collects and carries the surface runoff away from the reclamation area.

About eight months after this reclamation was completed, the main tunnel of drift opening 14 subsided for a distance of approximately 46 meters (150 feet) to the top of the hill. All subsidence occurred off of the project work area. No increase in water volume was observed as a result of this occurrence.

This strip area was revegetated using the same seed mixture and soil conditioning as strip H, previously discussed (Figure 42).

Lime	11 M.T./ha	(5 T/acre)
Fertilizer (10-20-20)	560 kg/ha	(500 lbs/acre)
Seeding: Tall Fescue	33.6 kg/ha	(30 lbs/acre)
Red Top	11 kg/ha	(10 lbs/acre)
Birdsfoot Trefoil	3.4 kg/ha	(3 lbs/acre)
Mulch: Straw or Old Hay	4.4 M.T./ha	(2 T/acre)

Figure 42. Revegetation, Section C, Strip J.

Strip mine J is 2.43 ha (6 A). Total reclamation costs were $14,790.00 which is $6,060.00/ha ($2,455.00/A). Area costs per reclamation item were:

Backfilling and Grading	$12,600.00
Agricultural Limestone	140.00
Fertilizer	280.00
Seeding and Planting	570.00
Mulching (all disturbed areas)	1,200.00

As with strip area H, a site investigation conducted in mid-December 1978 indicated that some routine maintenance in the form of reseeding and refertilization would have been beneficial here.

SECTION G - STRIP G (PRIORITY II)

The total length of this strip area is 366 meters (1,200 feet), the bench width is 15 meters (50 feet). The highwall averaged 11 meters (35 feet) and was highly fractured over its entire length. There were ten drift mine entries and several room interceptions along the highwall. The area had never been backfilled and there was considerable acidic material on both the bench and the outslope.

It appears that prior to strip mining this area, there were several drift mines located along the coal outcrop. It was suspected that each of these mines, if they were separate to begin with, were interconnected.

Mine opening complex 13-14-15-16 is located at the extreme northern end of the strip area. Water was draining from openings 13, 15, and 16. During regrading, openings 13, 14, and 15 were sealed with compacted spoil forcing the drainage to discharge through opening 16. The total flow amounted to approximately 26 liters per minute (7 gpm). Opening 16 was chosen as the discharge point since it appeared to have been the main haulageway for this complex and, consequently, was less prone to collapse.

The next mine opening complex is 17-18-19. Opening 18 was the main haulage tunnel and had a drainage of 26 liters per minute (7 gpm). This water combined with surface drainage from the southern half of the strip area and drained into a small tributary of Dents Run. Openings 20, 21 and 22 were suspected of being room interceptions into this mine complex, but this could not be confirmed.

There were several areas that apparently had intercepted deep mine workings; however, they had fallen in and were no longer accessible. Drift mine workings along the highwall were worked to the rise and any drainage would flow out of the mines rather than into the mines. Mine openings 16 and 18 were sealed with a rock wet seal to accommodate drainage. All other mine openings were sealed with compacted earth; this was done on the premise that all of these mines were interconnected and water would simply back up if sealed at one point and discharge from another opening. Unfortunately, this theory proved to be in error since mine opening 17 built up a head of water and broke through the earth seal onto the reclaimed strip bench. Due to the extensively fractured condition of the highwall, it was considered doubtful that any type of hydraulic seal would prevent future drainage from this area.

After sealing the various mine openings as discussed above, the strip area was regraded to a pasture type backfill. Rock lined drainage ditches were graded from each end of the strip bench toward the center where a natural drainage way conveyed water off of the reclamation area. The ditch conveying the water off of the bench was rock lined on the bench surface only. The outslope portion of the ditch was not disturbed during reclamation and the rock present from mining was sufficient to prevent erosion. The soil was conditioned with:

Lime	11 M.T./ha	(5 T/acre)
Fertilizer (10-20-20)	560 kg/ha	(500 lbs/acre)
Seeding: Tall Fescue	33.6 kg/ha	(30 lbs/acre)
Red Top	11 kg/ha	(10 lbs/acre)
Birdsfoot Trefoil	3.4 kg/ha	(3 lbs/acre)
Mulch (Old Hay)	4.4 M.T./ha	(2 T/acre)

Strip mine area G is 2.82 ha (7 A). At a reclamation cost of $17,185.00, this represents a unit cost of $6,090.00/ha ($2,455.00/A). Individual costs were:

Backfilling and Grading	$14,700.00
Agricultural Limestone	140.00
Fertilizer	280.00
Seeding and Planting	665.00
Mulching (all disturbed areas)	1,400.00

The regraded mine site was seeded on October 30, 15 days after the last generally acceptable fall planting date. Grass cover was very sparse in the spring and the contractor had to reseed the area.

During the reclamation design phase, it was decided that all of the mines were interconnected and that all but two of the openings could be sealed to divert water into drainage channels at these points. Unfortunately, this theory was either in error, or the compacted earthern seals were too pervious to impound drainage since a water seep saturated the reclaimed strip mine bench for a distance of 46 meters (150 feet). The drainage was quite acidic and would not support a vegetative cover.

Little, if any, post-reclamation maintenance was provided. Consequently, a field inspection conducted in December of 1978 revealed that a number of erosion gullies had developed, vegetative cover was sparse, and, in general, the mine site did not reflect the money spent on its reclamation (Figure 43).

SECTION G - STRIP P, Q (PRIORITY II)

Strip area P is located immediately below and parallel to strip Q. Much of the area had been covered by the outslope spoil material from strip area Q. No direct reclamation of strip area P was recommended because most of the bench was covered with either spoil from Q or heavy vegetation. It was decided that disruption of this existing vegetative cover would be counter productive.

The length of strip area Q is approximately 1.6 kilometers (one mile). The bench width averaged 38 meters (125 feet) with a highwall of 14 meters (45 feet) average height. There are eight drift mine openings on the western portion of the strip area, two of which had active discharges. Portions of the highwall were highly fractured, presumably caused by subsidence of drift mines. A large slip had occurred in the spoil material on the outslope. This slip area was approximately 91 meters (300 feet) long.

Reclamation efforts on this mine site consisted of placing a compacted earth seal in all drift mine openings except numbers 52 and 53, regrading along the entire length of the strip bench to establish drainage and help control slips, and removal and disposal of trash, debris, and junked automobile bodies. Rock wet seals were placed in mine openings 52 and 53 to allow drainage. [Drainage from these mines averages 11-19 liters per minute (3-5 gpm).]

An attempt was made to correct the slip but this was only partially successful. A slip of lesser magnitude reoccurred during the first winter following reclamation. The material over the Sewickley coal in this area is a clay shale that weathers to a slippery mud. During the surface mining operation this material was pushed over the hill in uncovering the coal; sandstone material was pushed over this shale in subsequent cuts. When water saturated this mudshale material, a slip occurred because of the weight of the

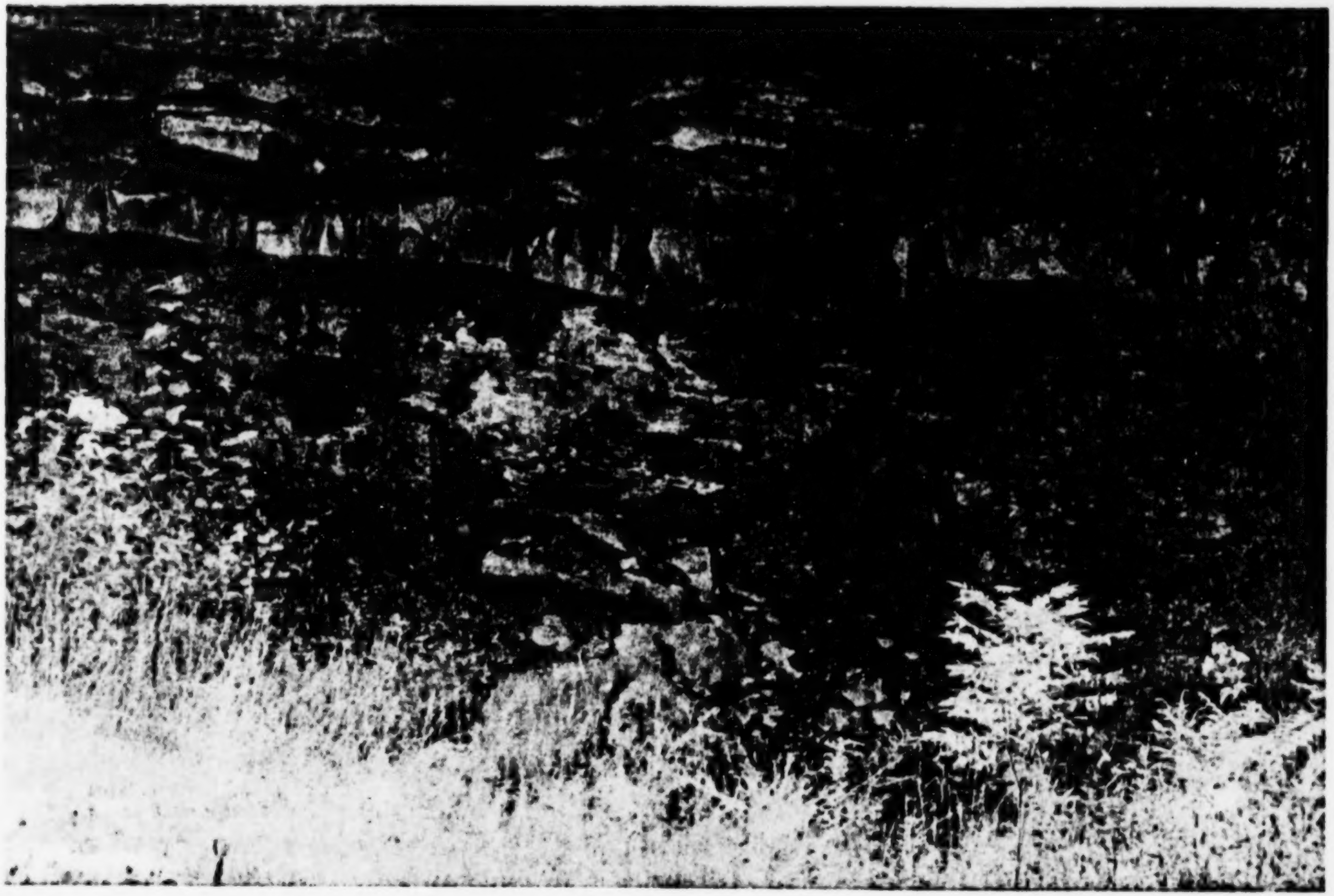


Figure 43. Reclamation, Section G, Strip G.

sandstone on the shale. During the reclamation of this area, a large amount of the sandstone was returned to the solid strip bench. However, the outslope remained overloaded and the slip reoccurred during the winter following regrading.

A pasture type backfill was used on the entire length of this strip area. The soil was conditioned and planted with:

Lime	11 M.T./ha	(5 T/acre)
Fertilizer (10-20-20)	560 kg/ha	(500 lbs/acre)
Seeding: Tall Fescue	33.6 kg/ha	(30 lbs/acre)
Red Top	11 kg/ha	(10 lbs/acre)
Birdsfoot Trefoil	3.4 kg/ha	(3 lbs/acre)
Mulch (old hay)	4.4 M.T./ha	(2 T/acre)

Reclamation cost on this area was $86,889.00 which is $6,480.00 per ha ($2,633.00/A). The site was 13.4 ha (33 acres). Item costs were:

Backfilling and Grading	$69,300.00
Agricultural Limestone	1,485.00
Fertilizer	1,254.00
Seeding and Planting	8,250.00
Mulching (all disturbed areas)	6,600.00

The drainage ditches from the two drift mines, 91 meters (300 feet) in length each, were rock lined for stability. Adequate ground cover grasses on the strip bench was realized during the first growing season. The outslope was planted in Black Locust seedlings, these appear to have done well during their first growing season.

An inspection conducted in December 1978 revealed that, in addition to the first slip area, a second very large slip had developed near the eastern end of this site. The new slip was also about 91 to 107 meters (300 to 350 feet) long.

At a second inspection in May 1979, vegetative cover, for the most part, appeared to be doing considerably better than the other reclaimed areas, although reseeding and fertilization could improve the aesthetics of this site by revegetating isolated bare spots. Figure 44 shows the vegetative success characteristics over most of the site.

SECTION G, STRIP AREA J (PRIORITY I)

Although this mine site was suspected to be an area of high infiltration, no work was done at this site due to the absolute refusal of the property owner to sign an agreement

Figure 44. Vegetative characteristics, Section G, Strip Q.

to allow the work to be done. This area was used as a commercial garbage dump by the property owner who operates a contract collection service for solid waste in the area. There is evidence that the area was auger mined and the strip mining operation had intercepted numerous underground workings.

The mine was regraded with a near level bench in the process of covering the garbage dump in the strip pit. Unfortunately, the backfill was completed with a thin layer of porous material, and received very little compaction. The material in the landfill itself was quite porous and the 3.64 ha (9 A) surface area could be the source of considerable drainage into underground mine workings.

SECTION 10

ANALYSIS AND EVALUATION

The Dents Run Watershed project was successful in many respects: aesthetic benefication, water quality improvements, restoring the utility of disturbed lands, elimination of environmental hazards such as burning gob piles and toxic refuse, and the reduction of surface water infiltration. It is unfortunate, however, that the success of the demonstration concept was not more carefully documented.

Under the original premise of evaluating set monitoring points during the demonstration period, analysis and evaluation would have been a relatively simple task. Borehole data would have been more than adequate to evaluate the effectiveness of the infiltration control measures employed by comparing the pre-reclamation pumping rates with post-reclamation pumping rates. Stream monitoring stations would have provided additional and substantiating data to further assess water quality improvement resulting from the combination of infiltration control and surface reclamation projects. Periodic surveillance of several key abandoned drift mine openings would have documented drainage reductions at these sites when evaluated against recorded rainfall data. Unfortunately, a number of unanticipated problems occurred during the project which interfered with the ability to perform a valid and conclusive evaluation of the success of the treatment techniques which were used.

The following presents a chronological synopsis of the factors affecting the project evaluation along with recommended solutions to avoid similar problems in future projects:

- Problem - Severe sedimentation behind the stream monitoring stations shortly after they were installed precludes their effective utilization as flow measuring devices (fall, 1972)

  Recommended Solution - Future projects conducted in disturbed watersheds should employ self-cleaning Parshall flumes or gauge natural stream beds to obtain flow measurements.

- Problem - Monitoring station equipment malfunctions and maintenance requirements dictate abandonment of plans for continuously recording stream water quality (winter, 1972 and 1973)

  Recommended Solution - Until remotely located field monitoring equipment has been perfected to the point that it can withstand the harsh environment of silt laden concentrated acid mine drainage, future studies should rely on periodic manual collection of water quality data.

- Problem - Consolidation Coal Company experiments with transferring drainage between boreholes, between coal seams, and between watersheds. Confirmed records of these investigations are not available (spring, 1973)

  Recommended Solution - Project personnel (consultants, government, industry, and public interest groups) should all work closely in order to coordinate data collection activities and adjust monitoring strategies if required to accommodate unforseen circumstances.

- Problem - Contractual problems lead to the cancellation of an engineering services contract. New project personnel are unfamiliar with some discharge points and fail to collect adequate monitoring data both before and after reclamation efforts. An example is flow documentation from underground mine opening 38 in section G (summer and fall, 1973)

  Recommended Solution - Obviously, the most acceptable method to resolve this type of problem is to monitor the project more closely to assure that unresolvable contractual problems do not occur. However, to cover this contingency, other project personnel should be totally familiar with all aspects of the project so that the project can continue without interruption in the event of personnel changes.

- Problem - Consolidation Coal Company's permanent transfer of Hess, Valotto, Six-Right, and Snider borehole discharges into the Indian Creek watershed (this in itself was not a significant problem; however, in so doing, this drainage was combined with an undetermined amount of drainage from other sources). Therefore, any possible reduction in volume resulting from reclamation efforts in the Dents Run watershed were marked by other undefined drainage (fall of 1974)

Recommended Solution - As previously recommended, closer coordination between all parties involved in the project.

A comparison can be developed to illustrate pre-reclamation and post-reclamation pumping rates versus rainfall by assuming that Consolidation Coal's borehole transfer experiments had little influence on the overall watershed pumping rates. Figure 45 graphically depicts the cumulative annual borehole pumpage and the precipitation for the years 1971 through 1974.

Borehole discharges for the years 1972 and 1974 are reported in Appendix A; precipitation records for these years are reported in Table 4. The years 1972 and 1974 were selected for anlaysis because the annual precipitation was nearly equal and these years are immediately before and after the reclamation effort within the watershed.

The pumping rates from the Snider and Loar boreholes were used in assessing the effectiveness of the project in reducing surface water infiltration. At the onset of the study, the Hess, Loar, Six-Right, Valotto, and Laurel Point boreholes discharged water from the Pittsburgh coal seam and the Snider borehole discharged water from the Sewickley seam. This system was later changed so that Hess, Six-Right, and Valotto boreholes were pumped underground into the Sewickley seam, which was then dewatered through the Snider borehole. The overall watershed pumping rates would reflect the total volume of water infiltrating the Dents Run watershed provided that no water was transferred from this area to another drainage basin. Assuming this to be correct, the decrease in the volume of water discharged from the Sewickley seam in 1972 and 1974 was:

Borehole	1972	1974
Snider	4.54×10^6 cubic meters (1.2×10^9 gallons)	3.31×10^6 cubic meters ($.88 \times 10^9$ gallons)

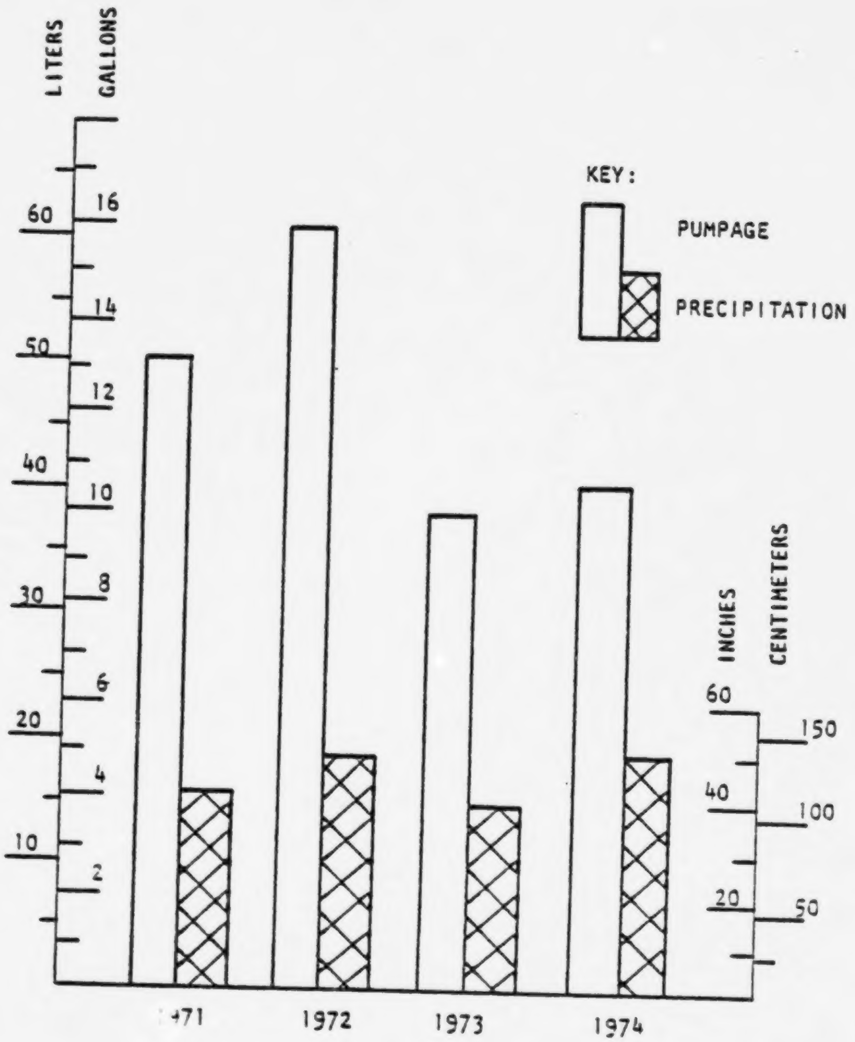


Figure 45. Borehole pumpage vs precipitation.

This resulted in a discharge reduction of:

4.54×10^6 cubic meters - 3.31×10^6 cubic meters =

1.23×10^6 cubic meters ($.32 \times 10^9$ gallons)

The percent reduction for this period was:

1.23×10^6 cubic meters $\div$ 4.54×10^6 cubic meters $\times$ 100 $\approx$

27 percent.

When the pumping rates recorded at Loar borehole were considered, the following discharges were realized:

Borehole	1972	1974
Snider	4.54×10^6 cubic meters (1.2×10^9 gallons)	3.31×10^6 cubic meters ($.87 \times 10^9$ gallons)
Loar meters	$.38 \times 10^6$ cubic meters (0.1×10^9 gallons)	$.12 \times 10^6$ cubic ($.03 \times 10^9$ gallons)
TOTAL	4.92×10^6 cubic meters (1.3×10^9 gallons)	3.43×10^6 cubic meters ($.90 \times 10^9$ gallons)

This resulted in a discharge reduction of:

4.92×10^6 cubic meters - 3.43×10^6 cubic meters =

1.49×10^6 cubic meters ($.40 \times 10^9$ gallons)

The percent reduction for this period was:

1.49×10^6 cubic meters $\div$ 4.92×10^6 cubic meters $\times$ 100 $\approx$

30 percent.

Although this percentage figure is short of the potential 50 percent reduction believed possible at the onset of this project, it, nevertheless, represents a very significant total volume of water - 3,400 cubic meters/day (900,000 gallons/day) from the combined discharges of the Snider and Loar boreholes.

The only discharge of any significance from abandoned underground mines was from mine opening 38 in Section G (refer to Figure 12). Flow measurements conducted at several times during the project tend to support the theory that there was a reduction in flow from this mine opening following regrading work on strip mine R, section G. Monitoring both before and after reclamation was inadequate to define the amount of this reduction with even the slightest degree of confidence.

The methodology utilized in performing the analysis on discharge reduction is a simplification of a very complex problem. This premise is based on the previously stated assumption that Consolidation Coal's borehole transfer experiments had little influence on the overall pumping rates. The validity of this discharge reduction is questionable, since visual observation would suggest that the amount of water transferred during tests was considerably more extensive than recorded by Consolidation Coal. Importance must be called to the fact that these tests were conducted at the same time that Priority I reclamation work was being completed. Therefore, it is difficult to determine whether the observed reduction in pumping was the result of modification to the water handling system, or was actually accomplished by the reclamation work being conducted. Attempting to interpret Consolidation Coal's pumping data between the Dents Run and Indian Creek watersheds would be even more suspect in the absence of good baseline data. Due to the absence of good baseline data, it may be assumed that reductions observed are indeed due to the mine sealing reclamation efforts.

Based on this information, a comparison between the cost of perpetual treatment and the one-time cost of reclamation can be performed. The cost of reclamation of Priority I areas was approximately $7,440.00 per hectare ($3,007.00/A).

Section C, Strip C	2,82 ha	7 A	$11,500.00
Section G, Strip A	4.05 ha	10 A	23,700.00
Section G, Strip R	6.47 ha	16 A	64,050.00
TOTALS	13.34 ha	33 A	$99,250.00

The reclamation affected a reduction of approximately 1.49 x 10^6 cubic meters (0.40 x 10^9 gallons) per year of water being pumped from the active mine workings. This represents a one-time cost for water elimination of:

($99,250 $\div$ 1.49 x 10^6 cubic meters) = $.07 per cubic meter = ($.25 per 1,000 gallons).

Although this cost figure alone is not particularly meaningful, it is quite significant when compared to the alternative cost of perpetual treatment. The cost of treating acid mine drainage of the quality associated with borehole discharges in this project was calculated from the cost of construction and operation of the two acid mine drainage treatment plants constructed by Consolidation Coal at Loar and Sears Farm.

Loar Initial Capital Cost ÷ 30 years	$ 8,100/year
Sears Initial Capital Cost ÷ 30 years	28,700/year
Operation and Maintenance (both plants)	117,500/year
	$154,400/year

According to Consolidation Coal Company officials, these plants treat a combined volume of 4.10 x 10^6 cubic meters/year (1.08 x 10^9 gallons/year). This amounts to a cost of:

$154,400 ÷ 4.10 x 10^6 cubic meters per year =

$.04 per cubic meter/year = ($.14 per 1,000 gallons/year)

The reclamation effort was shown to reduce the volume of mine drainage that was pumped from the underground operations by 1.49 x 10^6 cubic meters per year. Based on the $0.04 per cubic meter cost of operation of the Loar and Sears Treatment Facilities, this reduction in flow represents what would be approximately equivalent to a reduction in annual cost of:

1.49 x 10^6 cubic meters x $0.04/cubic meter = $59,600.

Since the cost of reclamation was $99,250 for Priority I areas, the one-time cost of reclamation versus the continued cost for treating 1.49 x 10^6 cubic meters per year would reach a break-even point of:

$99,250 ÷ $59,600/year = 1.7 years.

In addition to the more definable costs of treatment, the reclamation option also includes the less tangible benefits to aesthetic benefication and improved runoff control.

The cost of reclamation of Priority II areas was approximately $7,277 per hectare ($2,945/A).

Section C, Strip B	10.02 ha	25 A	$ 93,750.00
Section C, Strip H	2.83 ha	7 A	17,185.00
Section C, Strip J	2.43 ha	6 A	14,730.00
Section G, Strip G	2.82 ha	7 A	17,185.00
Section G, Strip Q	13.36 ha	33 A	86,889.00
TOTALS	31.57 ha	78 A	$229,739.00

This represents an incremental cost of less than \$163.00 per hectare (\$62/A) difference in the cost of reclamation using the special compaction techniques for reclamation employed in the Priority I mine sites as opposed to using conventional reclamation techniques as in the Priority II reclamation sites. Hopefully, the reclamation costs incurred in this project were much more than would be expected using a concurrent selective placement of material as mining progresses in an active operation.

Consolidation Coal's responsibility in this project was to control the pollution from their six active borehole discharges. Table 6 represents the average water quality and volume of drainage from these boreholes at the initiation of this project.

TABLE 6. CHRISTOPHER COAL COMPANY DIVISION DISCHARGES TO DENTS RUN - 1970

Borehole	Coal Seam	Average Flow GPD x 1000	pH	Acidity mg/l	Total Iron mg/l
Loar	Pittsburgh	230	2.8	1540	520
Laurel Point	Pittsburgh	150	2.4	3810	756
Snider	Sewickley	1800	6.1	(-27)	112
Six-Right	Pittsburgh	350	2.4	4370	878
Hess	Pittsburgh	420	2.7	4570	996
Valotto	Pittsburgh	45	2.7	1010	305

A very detailed study was conducted in the underground management of these discharges to see where and how these discharges could be directed and/or consolidated so as to minimize the number of treatment plants required. Two major facilities eventually evolved, the Loar Treatment Plant and the Sears Farm.

THE LOAR TREATMENT PLANT

The Loar discharge and the Laurel Point discharge were combined underground and an acid mine drainage treatment plant constructed at the Loar site. This plant consists of a conventional hydrated lime neutralization-aeration system and an impoundment for settling and sludge storage. The plant was designed for a flow of 637 liters/second (1,000 gpm), contains a dam 24 m (80 feet) high, and 259 m (850 feet) long, and impounds an area of approximately 5.3 ha (13 acres) with a capacity of 2.5 x 10^8 liters (65,000,000 gallons). It was designed for a 25-year life. This plant was activated in October 1973 and has operated satisfactorily since startup with no major problems. Recent water quality reported to the control agency as part of the federal water quality monitoring program has shown compliance with all applicable water quality standards. Table 7 shows typical water quality data before and after treatment, as analyzed and reported by Consolidation Coal.

TABLE 7. WATER QUALITY AT LOAR TREATMENT PLANT

Before		After
2.7	pH	8.2
3170 mg/l	Acidity	0
860 mg/l	Iron	< 2 mg/l
0	Alkalinity	> Acidity

THE SEARS TREATMENT PLANT

The Sears Plant consists of a conventional hydrated lime neutralization-aeration system and an impoundment for settling and sludge storage. The plant was designed for a flow of 252 liters/sec (4,000 gpm), contains an earthern dam 34 m (110 feet) high and 329 m (1,080 feet) long, and impounds an area of approximately 15 ha (38 acres) with a capacity of 1.89×10^9 liters (500,000,000 gallons). It was designed with a 25 year life. This plant was activated in September 1974. The discharge from this plant is reported to be in compliance with all applicable water quality standards. Table 8 shows typical water quality data before and after treatment as analyzed and reported by Consolidation Coal Company's Environmental Division.

TABLE 8. WATER QUALITY AT SEARS TREATMENT PLANT

BEFORE	COMPONENT	AFTER
3.3	pH	7.3
250 mg/l	Acidity	0
217 mg/l	Iron	2 mg/l
0	Alkalinity	Acidity

Consolidation Coal's cost for their participation in the Dents Run project was estimated to be in excess of $2,000,000.

Table 9 illustrates the overall water quality impact of the work conducted in the Dents Run watershed. Data from monitoring stations 1 and 4, which are located on Dents Run

TABLE 9. IMPACT OF DENTS RUN WATERSHED IMPROVEMENT (LOADS)

		Year 1971-72 Before Reclamation		Year 1976 After Reclamation		
		Dents Run Station No. 1 (Near Mouth)				
		Range	Mean	Range	Mean	Reduction (Percent)
Acidity	kg/day	5,140-8,600	6,870	34-256	122	98
	lb/day	11,300-18,900	15,100	74-565	269	
Total Iron	kg/day	1,600-1,650	1,620	2.6-288	114	93
	lb/day	3,520-3,600	3,560	5.8-634	251	
Sulfates (SO_4)	kg/day	13,100-21,400	17,250	2,200-11,000	6,270	64
	lb/day	28,800-47,200	38,000	4,900-25,000	13,900	
Total Dissolved Solids	kg/day	23,000-35,900	29,500	1,700-13,200	6,420	78
	lb/day	50,600-79,200	64,900	3,780-29,000	14,000	
		Dents Run Station No. 4 (One Mile Above Station No. 1)				
Acidity	kg/day	10,500-66,600	38,600	0-32	28	99
	lb/day	23,150-147,000	85,000	0-70	61	
Total Iron	kg/day	1,810-13,100	7,460	0.1-95	20	99
	lb/day	4,000-28,800	16,400	0.3-210	45	
Sulfates	kg/day	25,000-133,000	79,000	400-5,100	2,230	97
	lb/day	55,100-294,000	175,000	880-11,200	4,910	
Total Dissolved Solids	kg/day	40,600-243,000	141,800	567-7,270	3,240	98
	lb/day	89,400-535,000	310,000	1,250-16,000	7,140	

approximately one and two miles respectively upstream from the mouth, are shown. Station 4 shows a more dramatic reduction in loads (range 97 to 99 percent) than station 1 (range 64 to 98 percent). This is attributed to severely polluted mine drainage discharging from an active coal mine refuse pile between stations 1 and 4, therefore, the results at station 4 are more representative of the overall improvement on the watershed. Much of the water quality improvement depicted on this table is the direct result of transferring water from the Hess, Valotto, Six-Right, and Snider boreholes into a treatment plant in another watershed. This is pointed out merely to explain the reduction in sulfates and total dissolved solids, which would be higher if all of the drainage had been treated within the watershed.

In summary, this project represents one of the most comprehensive cleanup efforts ever attempted in a cooperative agreement by government and industry. Despite a number of individual problems throughout the course of this study, the total project was a success. This demonstration study presents an example of what can be accomplished through cooperative participation and a conscientious effort toward environmental improvement. With the increased emphasis placed on the reclamation of abandoned surface mined lands through the Federal Surface Mining Control and Reclamation Act of 1977, it appears that this type of specialized reclamation may be employed wherever physical conditions permit.

APPENDIX A

SUMMARY OF BOREHOLE PUMPING DATA 1971 - 1974

TABLE A-1. TABULATION OF BOREHOLE PUMPING BY QUARTERS, LITERS X 10^6

Quarter	Hess	Loar	Snider*	Total
1971				
3rd	0.7570	72.2398	552.9650	625.9618
4th	0.3986	90.6333	945.1122	1,036.1441
1972				
1st	3.1494*	84.2939*	798.5926	886.3590
2nd	7.7507*	127.1552*	1,295.4291	1,427.3350
3rd	2.1618*	57.8628*	1,195.0721	1,255.0967
4th	2.1226	113.9497	1,253.5920	1,369.6643
1973				
1st	0.3191	112.6704	1,160.4810	1,273.4705
2nd	0.3338	112.6810	702.2363	815.2511
3rd	0.3194	113.9497	538.3973	652.6664
4th	0.8157	113.9497	133.0511	247.8165
1974				
1st	3.8403	38.4071	879.0568	921.3042
2nd	3.4216	3.3140	1,173.0842	1,179.8198
3rd	2.6666	46.9461	758.0579	807.6706
4th	0.1509	33.1384	496.9947	530.2840

*Calculated from data other than project borehole monitoring equipment.

TABLE A-2. TABULATION OF BOREHOLE PUMPING BY QUARTERS, GALLONS

Quarter	Hess	Loar	Snider*	Total
1971				
3rd	200,000	19,085,800	146,093,800	165,379,600
4th	105,300	23,945,400	249,699,400	273,750,100
1972				
1st	852,065*	22,270,513*	210,988,800	234,091,370
2nd	1,255,148*	33,594,513*	342,253,400	377,103,060
3rd	571,163	15,287,400*	315,739,000	331,597,560
4th	560,800	30,105,600	331,200,000	361,866,400
1973				
1st	84,300	29,769,600	306,600,000	336,453,990
2nd	83,200	29,770,400	185,531,400	215,385,000
3rd	84,400	30,105,600	142,245,000	172,435,000
4th	215,500	30,105,600	35,152,200	65,473,300 3
1974				
1st	1,014,600	10,147,200	232,247,500	243,409,300
2nd	904,000	875,552	309,929,800	311,709,350
3rd	704,520	12,403,200	200,279,500	213,387,220
4th	39,880	8,755,200	131,306,400	140,101,480

Calculated from data other than project borehole monitoring equipment.

APPENDIX B

SUMMARY OF MONITORING STATION WATER QUALITY ANALYSES 1971 - 1975

Data is arranged by monitor station for the project period. Annual averages are reported for each station except for year 1971 and 1975. These two years only six months of project time was available. The data for 1971 represents six months collection time while the 1975 data represents only four months.

All analyses were performed as specified by "Standard Methods" and the Environmental Protection Agency "Methods for Chemical Analysis of Water and Waste Water."

The 1973 data is not reported because project personnel changes and monitoring equipment malfunctions during this period resulted in inadequate flow data.

TABLE B-1. SUMMARY OF WATER ANALYSIS - STATION 1

		1971	1972	1974	1975
Flow	CMD	11,898	113,145	33,967	91,480
	GPD	3,143,520	29,892,960	8,974,080	24,168,960
Acidity, Total	kg/da	8,579	5,136	4,770	8,735
	lbs/da	18,913	11,324	10,515	19,258
Alkalinity	kg/da		142		1,729
	lbs/da		313		3,812
Sulfate	kg/da	21,418	13,054	9,326	22,748
	lbs/da	47,217	28,778	20,560	50,151
Iron, Total	kg/da	1,598	1,645	722	1,092
	lbs/da	3,522	3,626	1,592	2,407
Solids, Total	kg/da	35,913	22,936	16,829	52,322
	lbs/da	79,174	50,565	37,102	117,553
Conductivity	mmhos	2,808	2,131	1,461	618
pH	Electrometrically	2.9	3.8	3.6	5.5

TABLE B-2. SUMMARY OF WATER ANALYSIS - STATION 2

		1971	1972	1974	1975
Flow CMD		1,254	7,282	10,481	10,901
GPD		331,200	1,923,480	2,769,120	2,880,000
Acidity, Total	kg/da	1,588	5,628	9,800	9,412
	lbs/da	3,502	12,407	21,605	20,749
Alkalinity	kg/da				
	lbs/da				
Sulfate	kg/da	4,055	13,095	19,631	15,592
	lbs/da	8,940	28,870	43,278	34,374
Iron, Total	kg/da	461	1,898	2,252	1,518
	lbs/da	1,017	4,184	4,964	3,346
Solids, Total	kg/da	6,595	28,516	35,530	25,882
	lbs/da	14,539	62,866	78,328	57,059
Conductivity	mmhos	4,213	3,054	2,429	2,300
pH	Electrometrically	2.6	3.2	3.1	3.0

TABLE B-3. SUMMARY OF WATER ANALYSIS - STATION 3

		1971	1972	1974	1975
Flow CMD		799	3,210	1,106	970
GPD		205,920	848,160	292,320	256,320
Acidity, Total	kg/da	1,083	8,440	2,146	509
	lbs/da	2,388	18,606	4,731	1,122
Alkalinity	kg/da				
	lbs/da				
Sulfate	kg/da	3,223	11,020	3,070	532
	lbs/da	7,105	24,294	6,769	1,173
Iron, Total	kg/da	417	1,910	460	74
	lbs/da	920	4,310	1,014	164
Solids, Total	kg/da	5,169	16,841	5,029	1,557
	lbs/da	11,395	37,128	11,086	3,432
Conductivity	mmhos	4,342	4,101	3,066	1,597
pH Electrometrically		2.5	2.5	2.9	4.0

TABLE B-4. SUMMARY OF WATER ANALYSIS - STATION 4

		1971	1972	1974	1975
Flow CMD		12,939	108,528	27,432	65,993
GPD		3,418,560	28,673,280	7,247,520	17,435,520
Acidity, Total	kg/da	10,502	66,605	6,276	3,282
	lbs/da	23,153	146,837	13,836	7,236
Alkalinity	kg/da				2,100
	lbs/da				4,631
Sulfate	kg/da	24,994	132,995	14,816	15,098
	lbs/da	55,102	293,199	32,664	33,285
Iron, Total	kg/da	1,814	13,062	928	656
	lbs/da	4,000	28,796	2,045	1,447
Solids, Total	kg/da	40,568	242,564	30,888	27,833
	lbs/da	89,435	534,754	68,095	61,361
Conductivity	mmhos	3,076	2,204	1,667	440
pH	Electrometrically	2.9	3.2	4.4	6.7

TABLE B-6. SUMMARY OF WATER ANALYSIS - STATION 6

		1971	1972	1974	1975
Flow CMD		1,101	12,569	1,875	6,857
GPD		290,880	3,320,640	495,360	1,811,520
Acidity, Total	kg/da	2,051	7,701	151	675
	lbs/da	4,522	16,978	333	1,489
Alkalinity	kg/da			306	894
	lbs/da			674	1,970
Sulfate	kg/da	4,243	17,127	571	1,944
	lbs/da	9,355	37,759	1,258	4,286
Iron, Total	kg/da	582	1,213	9	6
	lbs/da	1,282	4,878	19	14
Solids, Total	kg/da	6,599	33,130	1,701	6,631
	lbs/da	14,549	73,038	3,750	14,618
Conductivity	mmhos	5,212	2,783	864	780
pH	Electrometrically	3.0	4.2	7.6	7.8

TABLE B-7. SUMMARY OF WATER ANALYSIS - STATION 7

		1971	1972	1974	1975
Flow CMD		14,040		23,388	51,365
GPD		3,709,440	15,323,999	6,179,040	13,570,560
Acidity, Total	kg/da	12,944		6,793	1,073
	lbs/da	28,537	103,659	14,976	2,365
Alkalinity	kg/da			907	6,080
	lbs/da			2,000	13,404
Sulfate	kg/da	32,843		13,608	4,139
	lbs/da	72,406	165,855	30,000	9,124
Iron, Total	kg/da	2,974		791	31
	lbs/da	6,557	25,946	1,744	68
Solids, Total	kg/da	50,116		26,474	12,671
	lbs/da	110,486	344,937	58,364	27,934
Conductivity	mmhos	3,846	2,338	1,227	335
pH	Electrometrically	3.2	3.6	5.2	7.8

TABLE B-8. SUMMARY OF WATER ANALYSIS - STATION 8

		1971	1972	1974	1975
Flow	CMD	4,273	28,004	8,726	10,803
	GPD	1,128,960	7,398,720	2,305,440	2,834,080
Acidity, Total	kg/da	870	640	963	416
	lbs/da	1,919	1,412	2,124	917
Alkalinity	kg/da	509	1,643	764	1,354
	lbs/da	1,123	3,623	1,684	2,985
Sulfate	kg/da	6,111	23,313	5,389	1,440
	lbs/da	13,472	51,395	11,881	3,174
Iron, Total	kg/da	297	1,922	295	7
	lbs/da	655	4,237	651	15
Solids, Total	kg/da	9,275	41,473	11,160	3,696
	lbs/da	20,447	91,430	24,603	8,149
Conductivity	mmhos	2,990	1,528	1,216	450
pH	Electrometrically	6.6	7.0	7.1	7.9

TABLE B-9. SUMMARY OF WATER ANALYSIS - STATION 9

		1971	1972	1974	1975
Flow	CMD	6,764	42,949	17,501	35,139
	GPD	1,787,040	11,347,200	4,623,840	9,283,680
Acidity, Total	kg/da	12,319	46,095	13,700	1,049
	lbs/da	27,158	101,620	30,203	2,312
Alkalinity	kg/da				3,426
	lbs/da				7,552
Sulfate	kg/da	20,856	68,480	17,390	2,062
	lbs/da	45,980	150,971	38,339	4,546
Iron, Total	kg/da	2,531	9,441	2,089	35
	lbs/da	5,580	20,814	4,605	77
Solids, Total	kg/da	30,840	96,505	33,476	7,690
	lbs/da	67,990	212,753	73,800	16,953
Conductivity	mmhos	4,430	2,476	1,480	305
pH	Electrometrically	2.7	3.1	3.4	7.7

TABLE B-10. SUMMARY OF WATER ANALYSIS - STATION 10

		1971	1972	1974	1975
Flow	CMD	5,172	22,347	6,148	17,038
	GPD	1,366,560	5,904,000	1,624,320	4,501,440
Acidity, Total	kg/da	26	200	550	440
	lbs/da	57	441	1,213	971
Alkalinity	kg/da	761	2,534	874	1,728
	lbs/da	1,678	5,586	1,928	3,810
Sulfate	kg/da	504	1,534	458	932
	lbs/da	1,111	3,381	1,011	2,055
Iron, Total	kg/da	0.9	42	8	19
	lbs/da	2	93	18	41
Solids, Total	kg/da	1,769	7,335	1,761	3,830
	lbs/da	3,900	16,171	3,882	8,443
Conductivity	mmhos	518	407	392	282
pH	Electrometrically	7.9	7.5	7.4	7.8

APPENDIX C

INITIAL WATER QUALITY SAMPLING DATA AUGUST 1971 - JANUARY 1972

TABLE C-1. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 1*

Date	8/16/71	8/31/71	9/20/71	10/19/71	10/21/71	11/15/71	12/7/71	1/14/72
Flow (gpm)	620	2020	5334	980	-	1960	39400	16200
Pht. Alkalinity ($CaCO_3$)	-	-	-	-	-	-	-	-
M.O. Alkalinity ($CaCO_3$)	-	-	-	-	-	-	6.9	-
Free Acidity ($CaCO_3$)	820	200	33	617	550	194	-	40
Total Acidity ($CaCO_3$)	1280	640	119	816	1127	694	30	139
Conductivity (25°C) mmhos.	4190	3450	945	2770	3550	2540	650	1300
pH (electrometrically)	2.8	3.2	3.3	2.4	2.5	2.9	5.5	3.5
Color (APHA)	320	25	-	-	-	-	-	-
Turbidity (JTU)	72	140	-	-	-	-	-	-
Calcium (Ca)	470	281	94	231	265	346	66	100
Magnesium (Mg)	200	83	28	86	100	88	18	36
Hardness ($CaCO_3$)	1995	1043	-	931	1073	1226	238	398
Sulfate (SO_4)	3100	1480	570	1893	2380	1570	293	611
Total Iron (Fe)	280	76	95	134	184	102	106	48
Ferrous Iron (Fe)	16.8	11.5	5.1	20	23.5	12.3	10.6	6.8
Total Solids	4592	3480	1075	2985	3663	2482	2460	1093
Suspended Solids	20	128	141	102	83	115	1915	153
Dissolved Solids	4572	3352	934	2883	3580	2367	545	940
Settleable Solids (ml/l)	0.8	3.0	2.0	3.0	2.2	3.0	10.0	2.4
Aluminum (Al)	108	37	14	58	88.9	56.0	24.0	15.2
Manganese (Mn)	6.8	7.7	1.9	4.9	5.8	4.4	1.8	1.91
Chloride (Cl)	-	-	-	-	-	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-	-	-	-	694	4	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-2. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 2*

Date	8/31/71	9/20/71	10/19/71	11/15/71	12/7/71	1/14/72
Flow (gpm)	200	450	187	84	4480	1188
Pht. Alkalinity ($CaCO_3$)	-	-	-	-	-	-
M.O. Alkalinity ($CaCO_3$)	-	-	-	-	255	-
Free Acidity ($CaCO_3$)	560	394	942	571	-	221
Total Acidity ($CaCO_3$)	1080	780	1327	1142	106	407
Conductivity (25°C) mmhos.	4350	3730	4440	4100	1520	2370
pH (electrometrically)	3.0	2.9	2.2	2.7	6.7	2.8
Color (APHA)	75	-	-	-	-	-
Turbidity (JTU)	120	-	-	-	-	-
Calcium (Ca)	357	400	404	463	590	300
Magnesium (Mg)	151	142	208	174	62	80
Hardness ($CaCO_3$)	1512	-	1863	1871	1729	1078
Sulfate (SO_4)	2450	2500	3700	3124	1034	1314
Total Iron (Fe)	280	230	316	243	420	130
Ferrous Iron (Fe)	1.3	105	3.02	102	1.41	52.2
Total Solids	4878	4303	5660	4774	43536	2230
Suspended Solids	192	248	187	184	41780	277
Dissolved Solids	4686	4055	5473	4590	1756	1953
Settleable Solids (ml/l)	4.8	6.0	7.5	8.0	90	8.2
Aluminum (Al)	48	53	61.7	64	320	35
Manganese (Mn)	10.5	8.9	9.9	9.1	19	3.99
Chloride (Cl)	-	-	-	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-	-	1142	2	-

Test results reported in ppm unless otherwise noted.

*Refer to Figure 12 for location of sample point.

TABLE C-3. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 3*

Date	8/31/71	9/20/71	10/19/71	11/15/71	12/7/71	1/14/72
Flow (gpm)	100	50	117	74	420	297
Pht. Alkalinity ($CaCO_3$)	-	-	-	-	-	-
M.O. Alkalinity ($CaCO_3$)	-	-	-	-	-	-
Free Acidity ($CaCO_3$)	1640	658	1900	1734	458	1010
Total Acidity ($CaCO_3$)	3100	2080	3205	3010	624	1384
Conductivity (25°C) mmhos.	4700	3830	4300	4140	2000	3350
pH (electrometrically)	3.1	2.8	2.1	2.6	2.6	2.5
Color (APHA)	275	-	-	-	-	-
Turbidity (JTU)	70	-	-	-	-	-
Calcium (Ca)	398	380	438	428	232	290
Magnesium (Mg)	109	96	146	114	48	65
Hardness ($CaCO_3$)	1442	-	1694	1537	777	992
Sulfate (SO_4)	4370	3320	4461	3978	1214	2162
Total Iron (Fe)	680	500	580	610	106	375
Ferrous Iron (Fe)	26.3	20.4	7.55	20.6	7.42	27.0
Total Solids	7323	5907	7543	6488	2054	3675
Suspended Solids	9	11	138	58	150	60
Dissolved Solids	73	5896	7405	6430	1904	3615
Settleable Solids (ml/l)	<0.1	<0.1	2.0	<0.1	3	0.3
Aluminum (Al)	183	180	217	200	47	111
Manganese (Mn)	10.7	9.6	10.6	11.2	4.1	6.43
Chloride (Cl)	-	-	-	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-	-	2930	644	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-4. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 4*

Date	8/30/71	9/20/71	10/19/71	11/15/71	12/7/71	1/14/72
Flow (gpm)	3110	5400	1120	1620	26930	21663
Pht. Alkalinity ($CaCO_3$)	-	-	-	-	-	-
M.O. Alkalinity ($CaCO_3$)	-	-	-	-	0.5	-
Free Acidity ($CaCO_3$)	120	116	558	469	-	58
Total Acidity ($CaCO_3$)	420	322	1118	918	31.0	145
Conductivity (25°C) mmhos.	3600	1700	3100	2790	656	1350
pH (electrometrically)	3.2	3.1	2.6	2.8	4.5	3.4
Color (APHA)	5	-	-	-	-	-
Turbidity (JTU)	120	-	-	-	-	-
Calcium (Ca)	244	112	229	183	104	102
Magnesium (Mg)	91	44	104	72	21	32
Hardness ($CaCO_3$)	983	-	999	753	346	386
Sulfate (SO_4)	1750	910	2264	1686	287	669
Total Iron (Fe)	84	62	176	102	82	53
Ferrous Iron (Fe)	4.2	2.4	4.55	8.5	6.14	7.0
Total Solids	3435	1524	3573	2638	1021	1135
Suspended Solids	150	123	65	83	517	126
Dissolved Solids	3285	1401	3508	2555	504	1009
Settleable Solids (ml/l)	4.2	3.0	1.5	2.5	6	1.4
Aluminum (Al)	15.5	36	102	63	7.7	16
Manganese (Mn)	4.1	2.3	4.5	4.0	1.1	1.88
Chloride (Cl)	-	-	-	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-	-	847	24	-

Test results reported in ppm unless otherwise noted.

*Refer to Figure 12 for location of sample point.

TABLE C-5. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 5*

Date	8/30/71	10/19/71	11/15/71	12/7/71	1/14/72
Flow (gpm)	4040	1337	2673	28160	16159
Pht. Alkalinity ($CaCO_3$)	-	-	-	-	-
M.O. Alkalinity ($CaCO_3$)	-	-	-	7.4	-
Free Acidity ($CaCO_3$)	220	380	337	-	188
Total Acidity ($CaCO_3$)	620	812	826	33	382
Conductivity (25°C) mmhos.	3250	2600	2610	625	1980
pH (electrometrically)	3.2	2.7	2.9	5.8	2.8
Color (APHA)	15	-	-	-	-
Turbidity (JTU)	540	-	-	-	-
Calcium (Ca)	227	171	221	56	130
Magnesium (Mg)	85	69	76	18	10
Hardness ($CaCO_3$)	916	710	865	214	366
Sulfate (SO_4)	1990	1676	1513	169	895
Total Iron (Fe)	124	124	78	100	93
Ferrous Iron (Fe)	9.5	3.46	11.2	7.82	4.9
Total Solids	3649	2622	2400	2462	1482
Suspended Solids	156	100	116	1970	128
Dissolved Solids	3493	2522	2284	492	1354
Settleable Solids (ml/l)	6.3	5.5	4.5	11.0	5.0
Aluminum (Al)	40	76	54	19	22
Manganese (Mn)	4.0	2.8	3.3	1.2	3.9
Chloride (Cl)	-	-	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-	765	10	-

Test results reported in ppm unless otherwise noted.

*Refer to Figure 12 for location of sample point.

TABLE C-6. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 6*

Date	8/20/71	8/30/71	9/20/71	10/19/71	11/15/71	12/7/71	1/14/72
Flow (gpm)	140	185	844	45	297	6536	2228
Pht. Alkalinity ($CaCO_3$)	-	-	-	-	-	-	-
M.O. Alkalinity ($CaCO_3$)	-	-	-	-	-	15.9	-
Free Acidity ($CaCO_3$)	980	880	121	3	1050	-	80
Total Acidity ($CaCO_3$)	1540	1520	364	34	1693	34.8	183
Conductivity (25°C) mmhos.	8950	5800	2650	1800	4590	490	1500
pH (electrometrically)	2.9	3.0	3.0	4.4	2.5	6.1	3.2
Color (APHA)	190	140	-	-	-	-	-
Turbidity (JTU)	145	70	-	-	-	-	-
Calcium (Ca)	304	351	184	139	389	190	108
Magnesium (Mg)	155	177	72	47.9	156.0	9.2	42
Hardness ($CaCO_3$)	1396	1603	-	544	1613	513	442
Sulfate (SO_4)	3950	4870	1590	1033	3671	219	762
Total Iron (Fe)	680	340	104	7.3	380	136	66
Ferrous Iron (Fe)	39.8	1.9	11.7	1.02	59.4	5.54	15.6
Total Solids	6727	6525	2705	1617	5729	6684	1327
Suspended Solids	65	54	129	21	149	6244	192
Dissolved Solids	6662	6471	2576	1596	5580	440	1135
Settleable Solids (ml/l)	3.0	1.3	6.0	0.45	2.5	12.0	11.0
Aluminum (Al)	62	74	27	3	95	59	18
Manganese (Mn)	5.7	5.6	3.4	1.7	5.5	2.0	1.1
Chloride (Cl)	-	-	-	-	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-	-	-	1612	8.0	-

Test results reported in ppm unless otherwise noted.

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*Refer to Figure 12 for location of sample point.

TABLE C-7. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 7*

Date	8/20/71	8/30/71	9/20/71	10/19/71	11/15/71	12/7/71	1/14/72
Flow (gpm)	-	5300	4320	1569	1688	26890	13469
Pht. Alkalinity ($CaCO_3$)	-	-	-	-	-	-	-
M.O. Alkalinity ($CaCO_3$)	-	-	-	-	-	22.4	8
Free Acidity ($CaCO_3$)	2030	100	196	850	785	-	-
Total Acidity ($CaCO_3$)	3140	480	480	1658	1377	19	47
Conductivity (25°C) mmhos.	8150	3600	1870	3400	3050	570	1160
pH (electrometrically)	2.8	3.1	3.0	2.5	2.5	6.9	4.8
Color (APHA)	330	12	-	-	-	-	-
Turbidity (JTU)	110	520	-	-	-	-	-
Calcium (Ca)	183	247	118	252	205	52	90
Magnesium (Mg)	167	96	46	104	83	14	32
Hardness ($CaCO_3$)	1142	1011	-	1056	853	187	356
Sulfate (SO_4)	4500	2210	1020	2802	2177	217	557
Total Iron (Fe)	520	112	120	290	216	44	35
Ferrous Iron (Fe)	28.8	10.6	16.9	9.2	15.9	4.36	6.6
Total Solids	7098	3410	1945	4419	3449	888	983
Suspended Solids	33	200	179	156	188	371	111
Dissolved Solids	7065	3210	1766	4263	3261	517	872
Settleable Solids (ml/l)	0.6	8.5	6.0	4.0	7	4	1.1
Aluminum (Al)	180	29	48	122	98.0	3.1	9.0
Manganese (Mn)	7.6	3.6	1.8	4.6	5.0	0.63	1.0
Chloride (Cl)	-	-	-	-	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-	-	-	1377	12	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-8. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 8*

Date	8/30/71	9/20/71	10/19/71	11/15/71	12/7/71	1/14/72
Flow (gpm)	2660	990	93	79	11300	4019
Pht. Alkalinity ($CaCO_3$)	-	-	0	-	-	-
M.O. Alkalinity ($CaCO_3$)	52	106	163.5	158	39.0	79
Free Acidity ($CaCO_3$)	-	-	-	-	-	-
Total Acidity ($CaCO_3$)	12.0	3.2	10.0	8.0	20.0	15
Conductivity (25°C) mmhos.	3950	810	1320	1090	845	1740
pH (electrometrically)	6.2	7.8	8.2	7.8	6.6	7.0
Color (APHA)	140	-	-	-	-	-
Turbidity (JTU)	580	-	-	-	-	-
Calcium (Ca)	241	62	124	106	76	132
Magnesium (Mg)	88	22	38	31	22	48
Hardness ($CaCO_3$)	963	-	466	392	280	527
Sulfate (SO_4)	1620	287	593	414	350	810
Total Iron (Fe)	60.0	0.50	0.29	0.23	160	36
Ferrous Iron (Fe)	9.6	0.17	0.233	0.041	9.5	10.0
Total Solids	2904	581	1128	813	1595	1419
Suspended Solids	122	4	1	1	898	61
Dissolved Solids	2782	577	1127	812	697	1358
Settleable Solids (ml/l)	0.7	<0.1	<0.1	<0.1	7	0.2
Aluminum (Al)	<0.1	<0.1	<0.1	<0.1	4.5	0.15
Manganese (Mn)	3.8	0.72	0.21	0.28	2.5	1.58
Chloride (Cl)	-	-	-	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-	-	0	12	-

Test results reported in ppm unless otherwise noted.

**Refer to Figure 12 for location of sample point.*

TABLE C-9. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 9*

Date	8/30/71	9/20/71	10/19/71	11/15/71	12/7/71	1/14/72
Flow (gpm)	450	3362	1634	713	26890	8406
Pht. Alkalinity ($CaCO_3$)	-	-	-	-	-	-
M.O. Alkalinity ($CaCO_3$)	-	-	-	-	18.6	-
Free Acidity ($CaCO_3$)	980	206	813	275	-	56
Total Acidity ($CaCO_3$)	2280	458	1579	581	19.5	156
Conductivity (25°C) mmhos.	4450	1800	3250	2110	320	955
pH (electrometrically)	2.9	3.0	2.5	2.6	6.2	3.4
Color (APHA)	220	-	-	-	-	-
Turbidity (JTU)	170	-	-	-	-	-
Calcium (Ca)	193	98	230	205	36	60
Magnesium (Mg)	129	38	97	59	8.4	24
Hardness ($CaCO_3$)	1011	-	973	755	124	248
Sulfate (SO_4)	3410	936	2639	1156	117	414
Total Iron (Fe)	440	90	284	66	40	46
Ferrous Iron (Fe)	1.3	15.2	0.847	5.5	2.92	6.3
Total Solids	5647	1563	4093	1855	742	757
Suspended Solids	146	169	128	117	342	107
Dissolved Solids	5501	1394	3965	1738	400	650
Settleable Solids (ml/l)	5.7	6.0	4.0	5.0	6	2.7
Aluminum (Al)	141	40	122	46	3.1	18.0
Manganese (Mn)	6.2	1.6	4.4	3.2	0.40	0.69
Chloride (Cl)	-	-	-	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-	-	571	16	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-10. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 10*

Date	8/19/71	8/30/71	9/20/71	10/19/71	11/15/71	12/7/71	1/14/72
Flow (gpm)	5	30	2925	450	392	21364	3375
Pht. Alkalinity ($CaCO_3$)	-	-	-	-	-	-	-
M.O. Alkalinity ($CaCO_3$)	190	162	99	165	164	49	98
Free Acidity ($CaCO_3$)	-	-	-	-	-	-	-
Total Acidity ($CaCO_3$)	10.0	4.0	5.6	6.0	4.0	8.9	2.0
Conductivity (25°C) mmhos.	560	500	440	595	535	240	389
pH (electrometrically)	7.9	8.0	7.6	7.9	8.0	7.0	7.9
Color (APHA)	25	2	-	-	-	-	-
Turbidity (JTU)	<5	<5	-	-	-	-	-
Calcium (Ca)	51	53	44	61	80	56	48
Magnesium (Mg)	13	13	12	17	21.0	8.8	16
Hardness ($CaCO_3$)	181	186	-	223	286	176	186
Sulfate (SO_4)	140	110	78	107	99	50	76.7
Total Iron (Fe)	0.39	0.21	0.23	0.16	0.10	3.0	0.15
Ferrous Iron (Fe)	0.184	0.073	0.18	0.093	0.056	0.594	0.041
Total Solids	349	372	340	333	329	324	220
Suspended Solids	10	5	13	4	2	119	<1.0
Dissolved Solids	339	367	327	329	327	205	220
Settleable Solids (ml/l)	<0.1	<0.1	0.1	0.1	0.1	0.6	<0.1
Aluminum (Al)	0.18	<0.1	-	0.3	0.1	1.2	0.17
Manganese (Mn)	0.06	0.05	<0.1	0.02	0.04	0.26	0.02
Chloride (Cl)	-	-	-	-	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-	-	-	0	110	-

Test results reported in ppm unless otherwise noted.

*Refer to Figure 12 for location of sample point.

TABLE C-11. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 11*

Date	8/16/71	8/31/71	9/21/71	10/19/71	11/15/71	12/15/71	1/14/72
Flow (gpm)	100	60	35	56	56	-	-
Pht. Alkalinity ($CaCO_3$)	-	-	-	-	-	0	-
M.O. Alkalinity ($CaCO_3$)	-	-	-	-	-	0	-
Free Acidity ($CaCO_3$)	640	660	500	474	765	408	372
Total Acidity ($CaCO_3$)	990	1880	845	1071	1142	702	619
Conductivity (25°C) mmhos.	7780	4750	4350	4560	4350	3800	4430
pH (electrometrically)	2.8	3.4	2.9	2.6	2.5	2.8	2.8
Color (APHA)	>1000	110	-	-	-	-	-
Turbidity (JTU)	560	100	-	-	-	-	-
Calcium (Ca)	-	494	560	491	515	520	530
Magnesium (Mg)	-	192	156	184	179	216	180
Hardness ($CaCO_3$)	2912	2022	-	1982	2022	2185	2063
Sulfate (SO_4)	4280	3720	2900	3299	3259	3100	2800
Total Iron (Fe)	290	300	250	244	286	240	245
Ferrous Iron (Fe)	68.3	38.6	25.3	3.32	16.5	61.6	76.0
Total Solids	5492	5224	5145	5119	593	5050	4948
Suspended Solids	136	112	263	94	90	377	553
Dissolved Solids	5356	5112	4882	5025	503	4673	4395
Settleable Solids (ml/l)	12.0	4.0	5.0	1.1	1.6	10.0	11.5
Aluminum (Al)	60.0	49.0	58.0	55.5	47	52	40
Manganese (Mn)	8.4	7.7	7.8	8.4	8.4	7.35	8.06
Chloride (Cl)	-	-	-	-	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-	-	-	1142	784	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-12. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 12*

Date	8/16/71	8/31/71	9/20/71	10/19/71	11/15/71	12/15/71	1/14/72
Flow (gpm)	-	90	283	252	281	-	-
Pht. Alkalinity ($CaCO_3$)	200	-	-	-	-	0	-
M.O. Alkalinity ($CaCO_3$)	-	-	-	-	-	0	-
Free Acidity ($CaCO_3$)	1830	2120	1400	2305	2275	1484	2196
Total Acidity ($CaCO_3$)	3240	3760	2880	3610	3662	2204	3651
Conductivity (25°C) mmhos.	9350	5070	4520	4590	4340	3750	4890
pH (electrometrically)	2.7	2.8	2.4	2.5	2.4	2.6	2.5
Color (APHA)	392	460	-	-	-	-	-
Turbidity (JTU)	60	80	-	-	-	-	-
Calcium (Ca)	-	242	420	436	460	377	400
Magnesium (Mg)	560	131	130	151	142	136	110
Hardness ($CaCO_3$)	2220	1142	-	1709	1732	1500	1451
Sulfate (SO_4)	5240	4560	4560	4996	4625	3690	4364
Total Iron (Fe)	950	800	980	760	640	620	924
Ferrous Iron (Fe)	493	2.4	362	5.05	8.1	157	279
Total Solids	8164	8464	8093	8227	7529	5403	7872
Suspended Solids	24	7	15	151	36	26	38
Dissolved Solids	8140	8457	8078	8076	7493	5377	7834
Settleable Solids (ml/l)	0.1	<0.1	<0.1	1.5	0.1	<0.011	0.1
Aluminum (Al)	260	244	250	260	208	189	236
Manganese (Mn)	9.0	10.8	9.4	10.1	10.9	8.2	10.0
Chloride (Cl)	-	-	-	-	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-	-	-	3448	2320	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-13. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 13*

Date	8/16/71	8/30/71	9/20/71	10/19/71	11/15/71	12/15/71	1/14/72
Flow (gpm)	264	335	169	187	187	-	-
Pht. Alkalinity ($CaCO_3$)	-	-	-	-	-	0	-
M.O. Alkalinity ($CaCO_3$)	-	-	-	-	-	0	-
Free Acidity ($CaCO_3$)	480	1060	932	1408	1622	1810	1325
Total Acidity ($CaCO_3$)	1530	1880	1570	2142	2356	2630	2103
Conductivity (25°C) mmhos.	8640	6000	5500	5900	5560	5400	4910
pH (electrometrically)	2.9	3.1	2.9	2.5	2.4	2.6	2.5
Color (APHA)	280	240	-	-	-	-	-
Turbidity (JTU)	240	30	-	-	-	-	-
Calcium (Ca)	690	238	460	440	499	445	470
Magnesium (Mg)	310	218	192	202	200	236	220
Hardness ($CaCO_3$)	2996	1489	-	1928	2068	2080	2077
Sulfate (SO_4)	7610	4800	4510	5057	5058	4830	4367
Total Iron (Fe)	505	500	500	500	500	590	650
Ferrous Iron (Fe)	311	0.9	240	4.16	194	170	123
Total Solids	7720	7886	8027	7825	7862	7574	7774
Suspended Solids	16	75	122	196	196	40	347
Dissolved Solids	7704	7811	7905	7629	7666	7534	7427
Settleable Solids (ml/l)	6.0	2.1	2.0	5.0	0.7	0.4	4.2
Aluminum (Al)	78	93	82	114	117	141	137
Manganese (Mn)	7.4	6.3	5.6	5.8	6.6	5.8	6.74
Chloride (Cl)	-	-	-	-	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-	-	-	2356	2040	-

Test results reported in ppm unless otherwise noted.

*Refer to Figure 12 for location of sample point.

TABLE C-14. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 14*

Date	8/16/71	8/30/71	9/20/71	10/19/71	11/15/71	12/15/71	1/14/72
Flow (gpm)	-	840	-	672	-	-	-
Pht. Alkalinity ($CaCO_3$)	-	-	-	-	-	0	-
M.O. Alkalinity ($CaCO_3$)	-	-	-	-	-	0	-
Free Acidity ($CaCO_3$)	2500	2380	1140	2940	2468	2710	2570
Total Acidity ($CaCO_3$)	4230	4420	3850	4428	4900	4600	4505
Conductivity (25°C) mmhos.	11430	6250	6600	5400	6660	5800	7070
pH (electrometrically)	2.4	2.8	2.6	2.4	2.4	2.4	2.3
Color (APHA)	400	510	-	-	-	-	-
Turbidity (JTU)	110	90	-	-	-	-	-
Calcium (Ca)	-	150	500	468	481	464	460
Magnesium (Mg)	-	205	220	241	241	270	230
Hardness ($CaCO_3$)	2962	1215	-	2158	2191	2267	2093
Sulfate (SO_4)	5480	4880	6090	6584	6831	6390	5698
Total Iron (Fe)	900	600	860	720	740	980	930
Ferrous Iron (Fe)	372	3.0	306	10.2	308	396	367
Total Solids	10708	11167	10792	10621	10657	10490	10102
Suspended Solids	4	19	26	<1	6.0	18.0	58
Dissolved Solids	10704	11148	10766	10620	10651	10472	10044
Settleable Solids (ml/l)	0.1	<0.1	<0.1	<0.1	0.05	<0.1	<0.1
Aluminum (Al)	170	292	350	328	302	357	319
Manganese (Mn)	9.6	10.7	10.0	10.4	11.7	11.0	11.6
Chloride (Cl)	-	-	-	-	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-	-	-	4900	2520	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-15. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 15*

Date	8/30/71	12/7/71	1/14/72
Flow (gpm)	2800	-	-
Pht. Alkalinity ($CaCO_3$)	-	-	-
M.O. Alkalinity ($CaCO_3$)	48	58	106
Free Acidity ($CaCO_3$)	-	-	-
Total Acidity ($CaCO_3$)	52	190	177
Conductivity (25°C) mmhos.	3100	300	2920
pH (electrometrically)	5.8	5.6	6.1
Color (APHA)	110	-	-
Turbidity (JTU)	280	-	-
Calcium (Ca)	247	288	230
Magnesium (Mg)	91	88	85
Hardness ($CaCO_3$)	991	931	924
Sulfate (SO_4)	2020	1765	1538
Total Iron (Fe)	94	100	115
Ferrous Iron (Fe)	86	98	95.8
Total Solids	2951	3109	2663
Suspended Solids	72	112	52
Dissolved Solids	2879	2997	2611
Settleable Solids (ml/l)	0.2	0.2	<0.1
Aluminum (Al)	<0.1	0.13	0.15
Manganese (Mn)	3.9	4.0	3.82
Chloride (Cl)	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	10	-

Test results reported in ppm unless otherwise noted.

*Refer to *Figure 12* for location of sample point.

TABLE C-16. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 16*

Date	8/16/71	8/30/71	9/20/71	10/19/71	11/16/71
Flow (gpm)	44	50	50	35	30
Pht. Alkalinity ($CaCO_3$)	-	-	-	-	-
M.O. Alkalinity ($CaCO_3$)	-	-	-	-	-
Free Acidity ($CaCO_3$)	2810	2000	850	2192	2330
Total Acidity ($CaCO_3$)	4260	3940	3590	3840	4000
Conductivity (25°C) mmhos.	10540	5400	4900	4720	4890
pH (electrometrically)	2.7	3.0	2.7	2.5	2.6
Color (APHA)	920	440	-	-	-
Turbidity (JTU)	330	110	-	-	-
Calcium (Ca)	620	-	460	460	-
Magnesium (Mg)	285	-	192	218	-
Hardness ($CaCO_3$)	2719	-	-	2044	-
Sulfate (SO_4)	7360	5550	5270	5556	5647
Total Iron (Fe)	1000	920	920	780	760
Ferrous Iron (Fe)	285	156	149	9.23	80.7
Total Solids	9762	9566	9554	9433	9193
Suspended Solids	52	109	35	199	48
Dissolved Solids	9710	9457	9519	9234	9145
Settleable Solids (ml/l)	2.0	1.5	<0.1	2.0	0.1
Aluminum (Al)	304	280	290	300	294
Manganese (Mn)	8.0	7.9	6.8	7.5	8.1
Chloride (Cl)	-	-	-	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-	-	-	4100

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-17. WATER QUALITY ANALYSES
SAMPLE LOCATION NO. 17*

Date	8/19/71
Flow (gpm)	5
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	340
Free Acidity ($CaCO_3$)	-
Total Acidity ($CaCO_3$)	0
Conductivity (25°C) mmhos.	1175
pH (electrometrically)	8.2
Color (APHA)	15
Turbidity (JTU)	5
Calcium (Ca)	29
Magnesium (Mg)	16
Hardness ($CaCO_3$)	138
Sulfate (SO_4)	365
Total Iron (Fe)	0.29
Ferrous Iron (Fe)	0.092
Total Solids	743
Suspended Solids	4
Dissolved Solids	739
Settleable Solids (ml/l)	<0.1
Aluminum (Al)	<0.1
Manganese (Mn)	<0.02
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

*Refer to Figure 12 for location of sample point.

TABLE C-18. WATER QUALITY ANALYSES
SAMPLE LOCATION NO. 18*

Date	8/19/71
Flow (gpm)	10
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	-
Free Acidity ($CaCO_3$)	930
Total Acidity ($CaCO_3$)	1700
Conductivity (25°C) mmhos.	7150
pH (electrometrically)	2.9
Color (APHA)	200
Turbidity (JTU)	140
Calcium (Ca)	370
Magnesium (Mg)	114
Hardness ($CaCO_3$)	1392
Sulfate (SO_4)	3750
Total Iron (Fe)	364
Ferrous Iron (Fe)	11.9
Total Solids	5086
Suspended Solids	50
Dissolved Solids	5036
Settleable Solids (ml/l)	2.0
Aluminum (Al)	106
Manganese (Mn)	13.2
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

*Refer to Figure 12 for location of sample point.

TABLE C-19. WATER QUALITY ANALYSES SAMPLE LOCATION NO. 19*

Date	8/20/71	9/21/71
Flow (gpm)	25	37
Pht. Alkalinity ($CaCO_3$)	-	-
M.O. Alkalinity ($CaCO_3$)	-	-
Free Acidity ($CaCO_3$)	900	1140
Total Acidity ($CaCO_3$)	4090	6940
Conductivity (25°C) mmhos.	16500	9300
pH (electrometrically)	2.9	3.0
Color (APHA)	380	-
Turbidity (JTU)	270	-
Calcium (Ca)	145	380
Magnesium (Mg)	664	680
Hardness ($CaCO_3$)	3085	-
Sulfate (SO_4)	10054	9560
Total Iron (Fe)	2240	2940
Ferrous Iron (Fe)	1910	2150
Total Solids	16247	19661
Suspended Solids	129	438
Dissolved Solids	16118	19223
Settleable Solids (ml/l)	9.0	0.1
Aluminum (Al)	50	220
Manganese (Mn)	66.8	70.0
Chloride (Cl)	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-

Test results reported in ppm unless otherwise noted.

*Refer to Figure 12 for location of sample point.

TABLE C-20. WATER QUALITY ANALYSES SAMPLE LOCATION NO. 20*

Date	8/20/71
Flow (gpm)	-
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	-
Free Acidity ($CaCO_3$)	160
Total Acidity ($CaCO_3$)	200
Conductivity (25°C) mmhos.	1250
pH (electrometrically)	3.3
Color (APHA)	10
Turbidity (JTU)	5
Calcium (Ca)	84
Magnesium (Mg)	41
Hardness ($CaCO_3$)	378
Sulfate (SO_4)	541
Total Iron (Fe)	5.0
Ferrous Iron (Fe)	0.804
Total Solids	994
Suspended Solids	2
Dissolved Solids	992
Settleable Solids (ml/l)	<0.1
Aluminum (Al)	13.4
Manganese (Mn)	9.4
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

*Refer to Figure 12 for location of sample point.

TABLE C-21. WATER QUALITY ANALYSES
SAMPLE LOCATION NO. 21*

Date	7/27/71
Flow (gpm)	-
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	-
Free Acidity ($CaCO_3$)	412
Total Acidity ($CaCO_3$)	800
Conductivity (25°C) mmhos.	2950
pH (electrometrically)	2.7
Color (APHA)	70
Turbidity (JTU)	20
Calcium (Ca)	248
Magnesium (Mg)	87
Hardness ($CaCO_3$)	970
Sulfate (SO_4)	2250
Total Iron (Fe)	125
Ferrous Iron (Fe)	-
Total Solids	3596
Suspended Solids	64
Dissolved Solids	3532
Settleable Solids (ml/l)	0.5
Aluminum (Al)	65
Manganese (Mn)	5.9
Chloride (Cl)	7.86
Hot Pht. Acidity ($CaCO_3$)	-
Sodium	180
Potassium	5.5

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-22. WATER QUALITY ANALYSES
SAMPLE LOCATION NO. 22*

Date	8/16/71
Flow (gpm)	3-5
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	-
Free Acidity ($CaCO_3$)	40
Total Acidity ($CaCO_3$)	640
Conductivity (25°C) mmhos.	7310
pH (electrometrically)	4.8
Color (APHA)	380
Turbidity (JTU)	245
Calcium (Ca)	675
Magnesium (Mg)	280
Hardness ($CaCO_3$)	2836
Sulfate (SO_4)	3550
Total Iron (Fe)	328
Ferrous Iron (Fe)	301
Total Solids	4722
Suspended Solids	110
Dissolved Solids	4612
Settleable Solids (ml/l)	3.0
Aluminum (Al)	6.4
Manganese (Mn)	5.8
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-23. WATER QUALITY ANALYSES
SAMPLE LOCATION NO. 23*

Date	8/20/71
Flow (gpm)	0.5
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	-
Free Acidity ($CaCO_3$)	2130
Total Acidity ($CaCO_3$)	2760
Conductivity (25°C) mmhos.	6900
pH (electrometrically)	2.6
Color (APHA)	400
Turbidity (JTU)	80
Calcium (Ca)	128
Magnesium (Mg)	172
Hardness ($CaCO_3$)	1025
Sulfate (SO_4)	4250
Total Iron (Fe)	705
Ferrous Iron (Fe)	73.2
Total Solids	6634
Suspended Solids	21
Dissolved Solids	6613
Settleable Solids (ml/l)	<0.1
Aluminum (Al)	108
Manganese (Mn)	20.4
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

*Refer to Figure 12 for location of sample point.

TABLE C-24. WATER QUALITY ANALYSES
SAMPLE LOCATION NO. 24*

Date	8/20/71	9/20/71
Flow (gpm)	1-2	10
Pht. Alkalinity ($CaCO_3$)	-	-
M.O. Alkalinity ($CaCO_3$)	-	-
Free Acidity ($CaCO_3$)	580	508
Total Acidity ($CaCO_3$)	1150	1200
Conductivity (25°C) mmhos.	3800	2820
pH (electrometrically)	3.0	2.8
Color (APHA)	50	-
Turbidity (JTU)	10	-
Calcium (Ca)	297	300
Magnesium (Mg)	45	62
Hardness ($CaCO_3$)	927	-
Sulfate (SO_4)	1870	1890
Total Iron (Fe)	81	90
Ferrous Iron (Fe)	30.1	2.0
Total Solids	3251	3242
Suspended Solids	2.0	<1.0
Dissolved Solids	3249	3241
Settleable Solids (ml/l)	<0.1	<0.1
Aluminum (Al)	84	120
Manganese (Mn)	25.6	20.0
Chloride (Cl)	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-

Test results reported in ppm unless otherwise noted.

*Refer to Figure 12 for location of sample point.

TABLE C-25. WATER QUALITY ANALYSES SAMPLE LOCATION NO. 25*

Date	8/20/71	9/20/71
Flow (gpm)	1-2	135
Pht. Alkalinity ($CaCO_3$)	-	-
M.O. Alkalinity ($CaCO_3$)	-	106
Free Acidity ($CaCO_3$)	-	-
Total Acidity ($CaCO_3$)	-	5.2
Conductivity (25°C) mmhos.	505	445
pH (electrometrically)	7.2	7.8
Color (APHA)	20	-
Turbidity (JTU)	10	-
Calcium (Ca)	68	56
Magnesium (Mg)	14	13
Hardness ($CaCO_3$)	227	-
Sulfate (SO_4)	96	89
Total Iron (Fe)	0.23	6.5
Ferrous Iron (Fe)	0.067	0.47
Total Solids	341	631
Suspended Solids	9	304
Dissolved Solids	332	327
Settleable Solids (ml/l)	<0.1	0.5
Aluminum (Al)	<0.1	6.2
Manganese (Mn)	0.57	1.3
Chloride (Cl)	-	-
Hot Pht. Acidity ($CaCO_3$)	-	-

Test results reported in ppm unless otherwise noted.

*Refer to Figure 12 for location of sample point.

TABLE C-26. WATER QUALITY ANALYSES SAMPLE LOCATION NO. 26*

Date	7/27/71
Flow (gpm)	-
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	-
Free Acidity ($CaCO_3$)	1350
Total Acidity ($CaCO_3$)	2040
Conductivity (25°C) mmhos.	4445
pH (electrometrically)	2.4
Color (APHA)	>70
Turbidity (JTU)	54
Calcium (Ca)	490
Magnesium (Mg)	46
Hardness ($CaCO_3$)	1410
Sulfate (SO_4)	4486
Total Iron (Fe)	780
Ferrous Iron (Fe)	-
Total Solids	6832
Suspended Solids	140
Dissolved Solids	6692
Settleable Solids (ml/l)	4.0
Aluminum (Al)	222
Manganese (Mn)	7.5
Chloride (Cl)	<0.18
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

*Refer to Figure 12 for location of sample point.

TABLE C-27. WATER QUALITY ANALYSES
SAMPLE LOCATION NO. 27*

Date	7/27/71	8/30/71
Flow (gpm)	-	-
Pht. Alkalinity ($CaCO_3$)	-	-
M.O. Alkalinity ($CaCO_3$)	-	-
Free Acidity ($CaCO_3$)	1700	1300
Total Acidity ($CaCO_3$)	2340	2760
Conductivity (25°C) mmhos.	4325	5100
pH (electrometrically)	2.4	2.5
Color (APHA)	>70	260
Turbidity (JTU)	64	60
Calcium (Ca)	440	210
Magnesium (Mg)	37	152
Hardness ($CaCO_3$)	1250	1148
Sulfate (SO_4)	4152	4870
Total Iron (Fe)	670	460
Ferrous Iron (Fe)	-	1.9
Total Solids	7938	6729
Suspended Solids	84	64
Dissolved Solids	7854	6665
Settleable Solids (ml/l)	3.0	2.1
Aluminum (Al)	185	192
Manganese (Mn)	7.1	6.0
Chloride (Cl)	<0.18	-
Hot Pht. Acidity ($CaCO_3$)	-	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-28. WATER QUALITY ANALYSES
SAMPLE LOCATION NO. 28*

Date	8/19/71
Flow (gpm)	3-5
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	120
Free Acidity ($CaCO_3$)	-
Total Acidity ($CaCO_3$)	20
Conductivity (25°C) mmhos.	580
pH (electrometrically)	7.9
Color (APHA)	10
Turbidity (JTU)	5
Calcium (Ca)	75
Magnesium (Mg)	21
Hardness ($CaCO_3$)	274
Sulfate (SO_4)	220
Total Iron (Fe)	0.25
Ferrous Iron (Fe)	0.122
Total Solids	395
Suspended Solids	3
Dissolved Solids	392
Settleable Solids (ml/l)	<0.1
Aluminum (Al)	0.16
Manganese (Mn)	0.07
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-29. WATER QUALITY ANALYSES
SAMPLE LOCATION NO. 29*

Date	8/19/71
Flow (gpm)	1-2
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	160
Free Acidity ($CaCO_3$)	-
Total Acidity ($CaCO_3$)	15
Conductivity (25°C) mmhos.	510
pH (electrometrically)	7.9
Color (APHA)	5
Turbidity (JTU)	11
Calcium (Ca)	55
Magnesium (Mg)	16
Hardness ($CaCO_3$)	203
Sulfate (SO_4)	130
Total Iron (Fe)	0.28
Ferrous Iron (Fe)	0.125
Total Solids	307
Suspended Solids	2
Dissolved Solids	305
Settleable Solids (ml/l)	<0.1
Aluminum (Al)	0.12
Manganese (Mn)	0.10
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-30. WATER QUALITY ANALYSES
SAMPLE LOCATION NO. 30*

Date	8/19/71
Flow (gpm)	0.5
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	60
Free Acidity ($CaCO_3$)	-
Total Acidity ($CaCO_3$)	35
Conductivity (25°C) mmhos.	480
pH (electrometrically)	6.8
Color (APHA)	10
Turbidity (JTU)	10
Calcium (Ca)	55
Magnesium (Mg)	18
Hardness ($CaCO_3$)	211
Sulfate (SO_4)	220
Total Iron (Fe)	2.2
Ferrous Iron (Fe)	0.916
Total Solids	352
Suspended Solids	9
Dissolved Solids	343
Settleable Solids (ml/l)	0.1
Aluminum (Al)	0.96
Manganese (Mn)	0.31
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-31. WATER QUALITY ANALYSES SAMPLE LOCATION NO. 31*

Date	8/19/71
Flow (gpm)	2
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	150
Free Acidity ($CaCO_3$)	-
Total Acidity ($CaCO_3$)	25
Conductivity (25°C) mmhos.	480
pH (electrometrically)	7.3
Color (APHA)	0
Turbidity (JTU)	5
Calcium (Ca)	55
Magnesium (Mg)	16
Hardness ($CaCO_3$)	203
Sulfate (SO_4)	125
Total Iron (Fe)	0.21
Ferrous Iron (Fe)	0.053
Total Solids	321
Suspended Solids	13
Dissolved Solids	308
Settleable Solids (ml/l)	0.1
Aluminum (Al)	<0.1
Manganese (Mn)	<0.02
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-32. WATER QUALITY ANALYSES SAMPLE LOCATION NO. 33*

Date	8/31/71
Flow (gpm)	2
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	-
Free Acidity ($CaCO_3$)	1020
Total Acidity ($CaCO_3$)	1800
Conductivity (25°C) mmhos.	3400
pH (electrometrically)	3.3
Color (APHA)	250
Turbidity (JTU)	40
Calcium (Ca)	202
Magnesium (Mg)	114
Hardness ($CaCO_3$)	972
Sulfate (SO_4)	3400
Total Iron (Fe)	460
Ferrous Iron (Fe)	95
Total Solids	4256
Suspended Solids	12
Dissolved Solids	4244
Settleable Solids (ml/l)	0.1
Aluminum (Al)	51
Manganese (Mn)	15.4
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-33. WATER QUALITY ANALYSES SAMPLE LOCATION NO. 34*

Date	9/20/71
Flow (gpm)	140
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	138
Free Acidity ($CaCO_3$)	-
Total Acidity ($CaCO_3$)	6.4
Conductivity (25°C) mmhos.	678
pH (electrometrically)	7.9
Color (APHA)	-
Turbidity (JTU)	-
Calcium (Ca)	60
Magnesium (Mg)	18
Hardness ($CaCO_3$)	224
Sulfate (SO_4)	193
Total Iron (Fe)	0.14
Ferrous Iron (Fe)	0.045
Total Solids	507
Suspended Solids	11
Dissolved Solids	496
Settleable Solids (ml/l)	0.1
Aluminum (Al)	<0.1
Manganese (Mn)	0.24
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

*Refer to Figure 12 for location of sample point.

TABLE C-34. WATER QUALITY ANALYSES SAMPLE LOCATION NO. 36*

Date	9/20/71
Flow (gpm)	1
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	43.6
Free Acidity ($CaCO_3$)	-
Total Acidity ($CaCO_3$)	4.8
Conductivity (25°C) mmhos.	405
pH (electrometrically)	7.6
Color (APHA)	-
Turbidity (JTU)	-
Calcium (Ca)	36
Magnesium (Mg)	13
Hardness ($CaCO_3$)	143
Sulfate (SO_4)	124
Total Iron (Fe)	0.22
Ferrous Iron (Fe)	0.11
Total Solids	274
Suspended Solids	3
Dissolved Solids	271
Settleable Solids (ml/l)	<0.1
Aluminum (Al)	<0.1
Manganese (Mn)	0.19
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

*Refer to Figure 12 for location of sample point.

TABLE C-35. WATER QUALITY ANALYSES
SAMPLE LOCATION NO. 37*

Date	9/20/71	12/8/71
Flow (gpm)	23	-
Pht. Alkalinity ($CaCO_3$)	-	-
M.O. Alkalinity ($CaCO_3$)	28.4	48.0
Free Acidity ($CaCO_3$)	-	-
Total Acidity ($CaCO_3$)	316	17
Conductivity (25°C) mmhos.	1450	704
pH (electrometrically)	3.6	6.6
Color (APHA)	-	-
Turbidity (JTU)	-	-
Calcium (Ca)	170	90
Magnesium (Mg)	50	30
Hardness ($CaCO_3$)	630	348
Sulfate (SO_4)	797	298
Total Iron (Fe)	9.7	10.0
Ferrous Iron (Fe)	5.1	0.239
Total Solids	1335	704
Suspended Solids	24	66
Dissolved Solids	1311	638
Settleable Solids (ml/l)	0.1	0.1
Aluminum (Al)	18.0	4.5
Manganese (Mn)	4.5	1.4
Chloride (Cl)	-	-
Hot Pht. Acidity ($CaCO_3$)	-	24

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-36. WATER QUALITY ANALYSES
SAMPLE LOCATION NO. 38*

Date	11/15/71
Flow (gpm)	<0.5
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	204
Free Acidity ($CaCO_3$)	-
Total Acidity ($CaCO_3$)	4
Conductivity (25°C) mmhos.	750
pH (electrometrically)	8.0
Color (APHA)	-
Turbidity (JTU)	-
Calcium (Ca)	118
Magnesium (Mg)	27
Hardness ($CaCO_3$)	406
Sulfate (SO_4)	150
Total Iron (Fe)	1.8
Ferrous Iron (Fe)	0.20
Total Solids	461
Suspended Solids	8
Dissolved Solids	453
Settleable Solids (ml/l)	0.1
Aluminum (Al)	<0.1
Manganese (Mn)	0.60
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	0

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-37. WATER QUALITY ANALYSES
SAMPLE LOCATION NO. 39*

Date	10/21/71
Flow (gpm)	-
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	-
Free Acidity ($CaCO_3$)	2752
Total Acidity ($CaCO_3$)	4175
Conductivity (25°C) mmhos.	4100
pH (electrometrically)	2.3
Color (APHA)	-
Turbidity (JTU)	-
Calcium (Ca)	184
Magnesium (Mg)	142
Hardness ($CaCO_3$)	1042
Sulfate (SO_4)	5076
Total Iron (Fe)	1060
Ferrous Iron (Fe)	50.7
Total Solids	8797
Suspended Solids	18
Dissolved Solids	8779
Settleable Solids (ml/l)	0.2
Aluminum (Al)	211
Manganese (Mn)	31.1
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-38. WATER QUALITY ANALYSES
SAMPLE LOCATION NO. 40*

Date	10/28/71
Flow (gpm)	-
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	243
Free Acidity ($CaCO_3$)	-
Total Acidity ($CaCO_3$)	5.0
Conductivity (25°C) mmhos.	630
pH (electrometrically)	8.02
Color (APHA)	-
Turbidity (JTU)	-
Calcium (Ca)	81.3
Magnesium (Mg)	23.1
Hardness ($CaCO_3$)	437
Sulfate (SO_4)	108
Total Iron (Fe)	0.04
Ferrous Iron (Fe)	0.010
Total Solids	415
Suspended Solids	3
Dissolved Solids	412
Settleable Solids (ml/l)	<0.1
Aluminum (Al)	0.13
Manganese (Mn)	<0.05
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

TABLE C-39. WATER QUALITY ANALYSES - SAMPLE LOCATION NO. 41*

Date	10/28/71
Flow (gpm)	-
Pht. Alkalinity ($CaCO_3$)	-
M.O. Alkalinity ($CaCO_3$)	353
Free Acidity ($CaCO_3$)	-
Total Acidity ($CaCO_3$)	5.0
Conductivity (25°C) mmhos.	885
pH (electrometrically)	8.11
Color (APHA)	-
Turbidity (JTU)	-
Calcium (Ca)	33.4
Magnesium (Mg)	13.4
Hardness ($CaCO_3$)	139
Sulfate (SO_4)	122
Total Iron (Fe)	0.05
Ferrous Iron (Fe)	<0.005
Total Solids	563
Suspended Solids	2
Dissolved Solids	561
Settleable Solids (ml/l)	<0.1
Aluminum (Al)	0.19
Manganese (Mn)	<0.05
Chloride (Cl)	-
Hot Pht. Acidity ($CaCO_3$)	-

Test results reported in ppm unless otherwise noted.

Refer to Figure 12 for location of sample point.

APPENDIX D

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APPENDIX E

GLOSSARY

auger mining: Mining of coal from an exposed vertical coal face by means of a mechanically-driven boring machine which employs an auger to cut and remove the coal.

backfill: To place material back into an excavation and return the area to a predetermined slope.

bench: The leveled surface of an excavated area measured horizontally at any point in the overburden or spoil between the base of the highwall and the outer point or original fill bench, or a working base extending from the base of a highwall on which excavating equipment can set, move, and operate.

bench width: The width of the bench as measured horizontally from the base of the highwall to the outer point of the original fill bench.

contour surface mining: The removal of overburden and the mining of mineral that normally approaches the surface at approximately the same elevation, a contour bench resulting.

deep or drift mining: Removal of the mineral being mined without the disturbance of the surface as distinguished from surface mining.

diversion ditch: A machine-made waterway used for collecting groundwater or a ditch designed to change the actual or normal course of ground and/or surface water.

Georgia V-ditch: A ditch for the collection of ground and surface water, constructed on the solid bench area, with the opposing slopes being constructed in such a manner so as to permit the total area to be transversed by farm equipment.

highwall: The vertical or near-vertical wall consisting of the exposed overlying strata after excavating operation.

outer slope: The disturbed area extending from the outer point of the bench to the extreme lower limit of the disturbed land.

pushed down highwall: Reducing the height of a highwall on a surface mine by pushing the earth over the edge of the highwall onto the bench of the surface mine.

reclamation: The process of converting disturbed land to a stable form for productive use.

regrade or grade: To change the contour of any surface by the use of leveling or grading equipment.

spoil: All overburden material removed or displaced by excavating equipment, blasting, or other means.

stabilize: To settle, or fix in place by mechanical or vegetative means, including the planting of trees, grasses, vines, shrubs, or legumes.

seepage water: Any water entering the ground from the surface through capillary action, cracks, faults, or any other natural mode of entry and finding its way to the surface again.

storm water: Any water flowing over or through the surface of the ground caused by precipitation; generally surface runoff.

surface water: Water, from whatever source, which is flowing on the surface of the ground.